2004 Annual Report

July 1, 2003 – June 30, 2004

a technical report

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An overview of JISAO

Since 1977, the Joint Institute for the Study of the Atmosphere and Ocean (JISAO) has fostered research collaboration between the National Oceanographic and Atmospheric Administration (NOAA) and the University of Washington. On the NOAA side, the principal connection is the Pacific Marine Environmental Laboratory (PMEL), serving as host lab. JISAO is governed by 36 Senior Fellows, whose name and affiliations are listed in Appendix 1. The appointments are divided nearly evenly between University faculty and NOAA/PMEL personnel who hold affiliate faculty appointments at the University. The Director of JISAO reports to the University's Vice Provost for Research.

The research themes that JISAO has chosen to focus on reflect the particular research expertise and mutual interests of participating scientists at the University of Washington and NOAA. During the past year these themes have been revised to bring them into closer alignment with NOAA's strategic plan. The former "Estuaries" theme has been broadened to "Coastal Oceanography", and "Fisheries Recruitment" has been broadened to "Marine Ecosystems". With these changes, JISAO's four research themes become:

1) **Climate**
2) **Environmental Chemistry**
3) **Marine Ecosystems**
4) **Coastal Oceanography**

JISAO's **Climate** Theme encompasses the entire globe. Principal thrusts include tropical atmosphere-ocean interaction, global climate sensitivity, climate change in the Arctic, and the regional impacts of climate variability, with emphasis on the Pacific Northwest. It includes contributions to the global observing system, the development of climate models, and outreach to government agencies and businesses that have a stake in climate information. It is closely aligned with Goal 2 of NOAA's Strategic Plan *"Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond.*"

JISAO's **Environmental Chemistry** theme also addresses issues central to the U.S. Climate Change Science Program: namely, the carbon cycle and the sources, transformations, transports, and sinks of aerosols and trace gases. Like the Climate theme, it includes a strong observational component, with an emphasis on processes.

JISAO's **Marine Ecosystems** theme, mirrors Goal 1 in NOAA's strategic plan, *"Protect, Restore, and Manage the Use of Coastal and Ocean Resources through an Ecosystem Approach to Management."* It has a North Pacific focus, and it encompasses research on the impacts of climate variations on marine ecosystems and on ecosystems associated with underwater volcanoes -- hydrothermal vents. Hydrothermal vents support unique and poorly understood marine ecosystems that can affect the biological, chemical, and thermal variablity of the oceans. Some hydrothermal microorganisms have potential application to serve society in drug development and toxic waste management as well as serving research on the origins of life. JISAO's Marine Ecosystems theme also includes an applied research component in support of

fisheries management, with emphasis on salmon and walleye Pollock and the ecosystem of the California Current system, with particular emphasis on sardines and hake. Some of the JISAO research on Marine Ecosystems is carried out in cooperation with NOAA scientists at the Alaska Fisheries Science Center (AFSC) and the Northwest Fisheries Science Center (NFSC).

JISAO's **Coastal Oceanography** theme is currently dominated by research and development on tsunami preparedness, a major concern of residents and visitors to coastal communities in the Pacific Northwest. This activity is aligned with NOAA's Goal 3 *"Serve Society's Needs for Weather and Water Information"* and has broader implications for the safety of life and property in the coastal zone, which clearly falls within the scope of NOAA's mission.

JISAO maintains a modest ongoing research and development effort in Information Technology, which supports all four of its research themes, and serves the broader NOAA community and the geosciences community at large.

The research carried out in JISAO is divided into three tasks:

- **Task I,** the Institute's "core program", to which the University contributes, supports, on average, two postdoctoral fellows on annual appointments, which are renewable for a second year, and also senior visitors on leave from their home institutions. JISAO provides space, computer time, administrative support, and other services for these individuals. It also provides travel expenses and honoraria for short-term visitors, as documented in Appendix 2. In addition, Task I provides a percentage of the salaries for the JISAO administrator and one budget analyst, who manage and support the institute's business and financial operations.

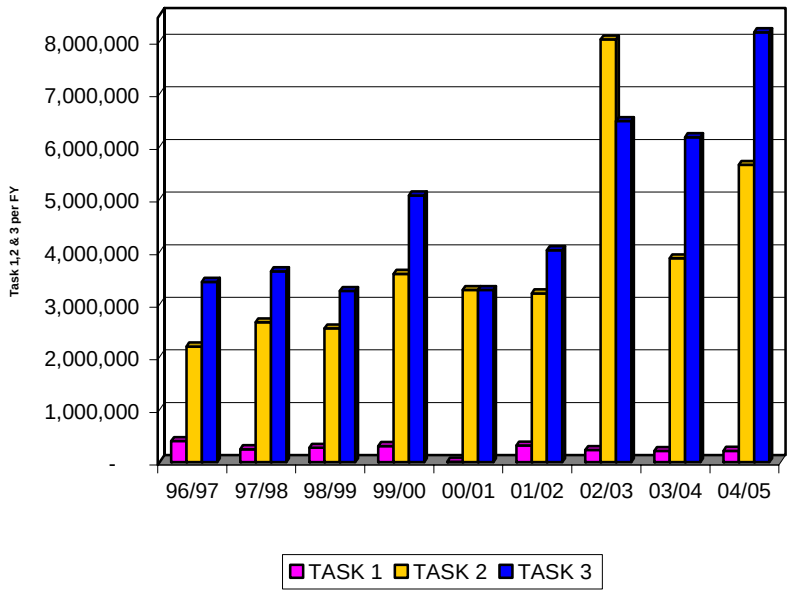
- **Task II** serves as a vehicle for funding research scientists (UW professional staff), post-doctoral research associates and graduate students through the JISAO Cooperative Agreement grant. The Task II program supports directed, collaborative research efforts between NOAA and university scientists.

- **Task III** supports University of Washington research in areas compatible with the Institute's major research themes. Along with Task II, Task III programs serve as vehicles for funding research scientists (UW professional staff), postdoctoral research associates and graduate students through the JISAO Cooperative Agreement grant.

Executive Summary

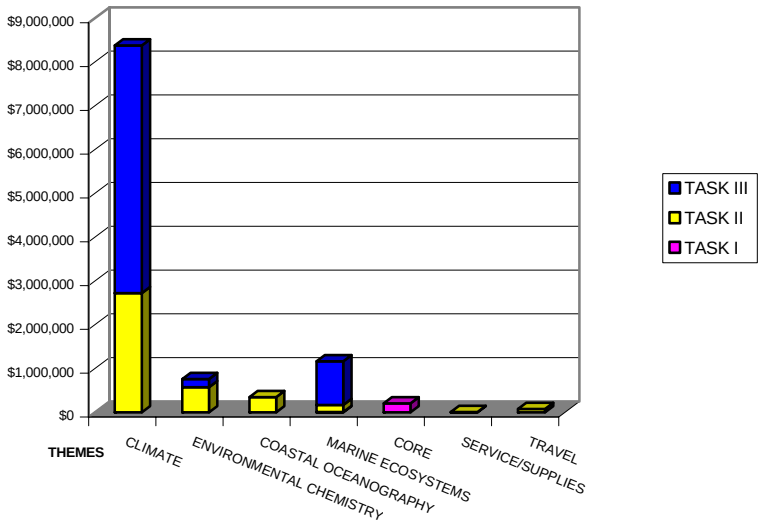
A history of NOAA funding for JISAO since 1996 is shown in Figure 1. The total for all Tasks in 2003-04 amounted to $10,257,168.

Fig. 1 JISAO Task 1, 2 & 3
Funding History 1996-2005



A breakdown of funding for 2003-04 by Task and Theme is shown in Figure 2:

Fig. 2
JISAO FUNDING BY TASK & THEME 2003/2004



Task I funding supported one postdoc (Andrew Rice) and the 17 short term visitors listed in Appendix 2. Task II funding supported a total of 65 professional staff housed at NOAA/PMEL, whose names and titles are listed in Appendix 3. It also supported four postdocs (Carlos Alvarez-Flores, Lorenzo Ciannelli, Yong Woo Lee, and Franz Mueter.), who are housed at the Alaska Fisheries Science Center. Task III supported four postdocs (Jennifer Boldt, Jesús Jurado-Molina, Carolina Parada-Veliz, and Yungbing Shi. University of Washington grants and principal investigators on NOAA grants funded through Task III are listed in Appendix 4.

Here we highlight some of the more prominent accomplishments of the research supported under the respective themes.

Climate

- deploying and maintaining key components of the Global Ocean Observing System in support of seasonal to interannual climate prediction and the monitoring of longer term natural and human-induced climate change. A total of 105 Argo floats were deployed, 60 of which were placed in remote regions of the southwest Pacific. The Tropical Atmosphere and Ocean (TAO) array of moored buoys in the tropical Pacific and the Pilot Research Moored Array in the Tropical Atlantic (PIRATA) were maintained.

- constructing and field testing the "Seaglider", an autonomous undersea vehicle capable of carrying out over a thousand hydrographic sections to a depth of 1000 meters in a single voyage.

- providing real time data from TAO and related buoy arrays to the scientific community via a state-of-the-art web site. As a measure of the success of this effort, the TAO Project was awarded the Grace Hopper Government Technology Award for innovative application of information technology in December 2003.

- analyzing data from the TAO array and a variety of other tropical atmosphere and ocean datasets, with emphasis on ENSO and other phenomena that contribute to year-to-year and decade-to-decade climate variability, as well as the pronounced week-to-week variability in tropical rainfall that is observed within individual seasons.

- coordinating of a national effort to reduce the uncertainties in estimates of present and future greenhouse warming due to cloud feedbacks, in support of the U.S. Climate Change Science Program.

- characterizing climate change over the Arctic, and placing it in a long term historical context. Elements examined include sea-ice, extent of tundra, sea surface temperatures in the Bering and Beaufort Seas and the exchange of fresh water between the Arctic and North Atlantic Oceans.

- developing an experimental hydrological forecast system suitable for use over the western United States.

- Assessing the impacts of climate variability and human-induced climate change on the availability of water and other resources in the Pacific Northwest.

Environmental Chemistry

- estimating the amount of carbon that has accumulated in the World Ocean from the time of the Industrial Revolution up until 1994 as a result of the burning of fossil fuels and deforestation.

- estimating the rate of dissolution of calcium carbonate in the World Ocean. The estimated rate has proven to be high enough to raise concerns about the future health of coral reefs and other shell forming organisms.

- participating in and synthesizing measurements from recent field campaigns designed to characterize the chemical composition of aerosols over specific regions such as New England.

- making automated measurements of dimethylsulfide (DMS) concentrations in sea water on board the R/V Ronald H. Brown.

- hosting the International Global Atmospheric Chemistry Program Office.

- streamlining field measurements of isotopic hydrogen and developing a method for measuring the concentration and isotopic composition of formaldehyde in the atmosphere, and characterizing the spatial and temporal variability of these species.

Marine Ecosystems

- developing the computer code and infrastructure required to embed simple ecosystem models within physically based, grid-point models that resolve currents, regions of upwelling and downwelling, and the chemical makeup of ocean water with varying degrees of spatial resolutions, along with the software required to visualize the complex time varying spatial fields generated by these models.

- developing a suite of more quantitative indicators for characterizing the status of the North Pacific ecosystem as it responds to climate variability and human intervention.

- evaluating the performance of the various statistical methods used to predict the recruitment of species such as walleye Pollock on the basis of environmental indicators.

- assessing whether climate variations may have contributed to the recent decline of Steller sea lion populations in the Aleutian Islands.

- obtaining and analyzing water samples from two hydrothermally active sites on the sea floor where conditions are quite different from those encountered in the better

documented mid-ocean ridge (divergent plate margin) environment.

- participating in field expeditions in the Marianas Volcanic Arc, which provided the first direct observations of volcanic activity in the deep sea, overlapping hydrothermal and photosynthetic ecosystems, and the venting of liquid carbon dioxide.

- participating in a multi-year field program linking chemical and microbiological processes along the Juan de Fuca ridge.

Coastal Oceanography

- providing measurements in support of Project DART (Deep-ocean Assessment and Reporting of Tsunamis) and the U.S. National Tsunami Hazard Mitigation Program.

- developing community-specific inundation maps to assist states and municipalities in assessing tsunami hazards.

- developing the methodology for providing tsunami forecasts in real time to provide guidance in issuing warnings.

Information Technology

Cutting across JISAO's four themes is a suite of activities that can best be described as Outreach, in the broad sense of the term. Included in this category are websites designed to make

- observations from the TOGA TAO array,
- other frequently used climate datasets,
- data on climate impacts in the Pacific Northwest,
- ocean carbon dioxide data from PMEL/JISAO and elsewhere,
- DMS measurements, and
- Bering Sea ocean data readily accessible to the scientific community.

The JISAO Information Technology group is also developing and refining web-based tools for accessing, managing, graphically representing, visualizing, and interactively exploring today's voluminous multi-dimensional datasets. Outreach also includes the countless personal interactions, like the ongoing dialogue between the Climate Impacts Group and stakeholders in the Pacific Northwest, conversations with the press and the public on the topic of the day, and service on the numerous national and international committees that plan and manage programs that NOAA has an interest in.

JISAO Research Projects

Climate

Global Ocean Observing System

(Tasks II and III, S. Riser and G. Johnson, co-PI's)[1]

This international Argo program, a central component of the Global Ocean Observing System, is designed to deploy 3000 profiling floats in the world ocean (approximately 300 km resolution over the globe) that will collect profiles of temperature and salinity over the upper 1000 m of the world ocean at approximately 10-day intervals. This is the first subsurface global ocean observing system. The United States is committed to providing about half of these floats. For the past 2 years, the US has been providing about 300 floats per year. Responsibility for deploying the floats is split among Scripps Institution of Oceanography, Woods Hole Oceanographic Institution, and University of Washington.

Goal 1: To deploy profiling floats in support of NOAA's contribution to the international ARGO Program.

Accomplishments:

- **Deployments.** A total of 105 floats were deployed in the Indian, Antarctic, and South Pacific Oceans. Until recently, relatively few Argo floats have been deployed in the South Pacific, where few ships or aircraft are available to support deployment operations. To remedy this situation, NOAA channeled funds through JISAO to charter a vessel for several months. Original plans were to use a Russian research vessel for this work. After investigating the availability of vessels, it was decided instead to use a small research vessel based in Wellington, New Zealand, operated by the National Institute of Water and Atmospheric Research of New Zealand. In all, this vessel deployed 60 Argo floats supplied by JISAO and 80 floats supplied by Scripps in the South Pacific region during calendar year 2004. These floats greatly increase the available database for the South Pacific, and their data are already being assimilated into climate models.

Goal 2: To use data from the floats to monitor ocean climate.

Accomplishments:

- **Preliminary analyses** using Argo data are being used to examine the state of the Indian Ocean Dipole and the Pacific Decadal Oscillation in the North Pacific. Long-term (decade to century) scale of variability of salinity in the North Pacific is also under investigation.

[1] PIs and NOAA personnel are listed in plain text. JISAO project personnel are listed in boldface, and graduate students are in bold italics.

Tropical Atmosphere-Ocean Interaction

(Task II: M. McPhaden, D.E. Harrison, **G. Vecchi**, **P. Ahearn, W. Cheng, D. Dougherty, C. Fey, M. McCarty, D. McClurg, S. Noor, T. Sawatzky, Y. Serra, L. Stratton, D. Zhang, D. Zimmerman**, ***X. Zhang*****)**

JISAO research on tropical atmosphere-ocean interaction seeks to improve understanding and prediction of El Niño and the Southern Oscillation (ENSO). The centerpiece of the ENSO observing system is the Tropical Atmosphere Ocean (TAO) mooring array, designed to monitor variability in the tropical upper ocean and at the surface. The TAO array is maintained by NOAA and JISAO scientists at PMEL. In combination with the TRITON array maintained by Japanese scientists in the western Pacific, it is comprised of 70 moorings at 11 different longitudes, spanning the equator from 8°S to 8°N. In addition to monitoring ENSO, data from the array are used for ENSO forecasting and a variety of oceanographic and climate research studies. The array provides long-term, large-scale context for process oriented field studies such as the Eastern Pacific Investigation of Climate (EPIC). It also supports carbon cycle studies in the Pacific, by providing access to ship and buoy platforms and by providing a physical oceanographic and meteorological context in which to interpret chemical measurements.

Complementing the TAO array in the tropical Pacific is the Pilot Research Moored Array in the Tropical Atlantic (PIRATA), maintained by NOAA and JISAO scientists at PMEL in collaboration with institutions in Brazil and France. This array of 10 moorings provides data to advance our understanding and ability to predict intraseasonal-to-decadal variations in the climate of the Atlantic sector. Together, TAO and PIRATA are managed through the TAO Project Office at PMEL.

Goal 1: To ensure high quality and timely access to moored time series data for climate research.

Accomplishments:

- **Providing TAO data to the scientific community via the Internet.** Research carried out at JISAO and elsewhere using data from the TAO/TRITON and PIRATA arrays depends critically on the collection, quality control, archival, and web-based display and dissemination of mooring data sets. At JISAO, considerable effort is devoted to providing easy access to high quality multi-variate time series through the TAO web page (*http://www.pmel.noaa.gov/tao/*). As a measure of success, the TAO Project Office was awarded the Grace Hopper Government Technology Award for Innovative Application of Information Technology in December 2003.

Goal 2: To contribute to our understanding of the ENSO cycle.

Accomplishments:

- **Westerly wind events and ENSO.** The role of large-scale dynamics and of episodic westerly wind forcing in governing the evolution of the 2002-03 El Niño was examined. A fundamental scientific question is whether or not ocean-atmosphere feedbacks in the tropical Pacific lead to a self-sustaining ENSO cycle. In other words, does ENSO represent an intrinsic instability of the coupled ocean-atmosphere system with natural

oscillations between unusually cold and warm conditions? Or is ENSO better thought of as a series of discrete warm events punctuating periods of neutral or unusually cold conditions? In the latter case, ENSO can be characterized as a damped or stable oscillator, in which atmospheric forcing associated with weather variations is required to initiate and sustain individual El Niño events. Weather phenomena are inherently unpredictable more than a few weeks in advance. Thus, they represent a source of noise that limits ENSO predictability. While results from a single case study cannot be definitive, it is clear that episodic westerly wind forcing played a significant role in the timing, amplitude, and termination of the 2002-03 El Niño. This episodic forcing also confounded seasonal forecasting efforts, particularly during the onset phase of the event.

Goal 3: To better understand intraseasonal variability and its links to climate.

Accomplishments:

- **Westerly wind events and the Madden-Julian Oscillation (MJO)**. Westerly wind events (short duration episodes of equatorial westerly wind anomaly) are not synonymous with the westerly phase of the MJO. Although westerly wind events occur preferentially during the convectively active phase of the MJO over the western and central equatorial Pacific, it is shown that the probability of a westerly wind event occurring during the westerly phase of the MJO is statistically indistinguishable from it occurring at other times. It is further shown that there is equatorial Pacific SST warming in the cold tongue following the westerly phase of the MJO only when it was coincident with a westerly wind event.

- **Intraseasonal variability in the Atlantic.** Significant intraseasonal variability in surface atmospheric and oceanic properties with periods of 30-70 days was discovered. This variability is evident in the North Atlantic Oscillation and its Southern Hemisphere counterpart; it may in part be related to the Madden-Julian Oscillation, which originates over the Indian Ocean. Fluctuations at periods of 30-70 days significantly affect tropical surface winds, latent heat fluxes, and sea surface temperatures. Like intraseasonal variability in the tropical Pacific Ocean, it may affect the evolution of longer-term seasonal-to-decadal time scale variability in the Atlantic.

Goal 4: To advance our understanding of decadal variability in the tropical oceans.

Accomplishments:

- **Observational studies.** Dramatic changes in the shallow meridional overturning circulation in the Pacific Ocean over the past half century have been documented and related to variations in the depth of the equatorial thermocline, tropical Pacific SSTs and global scale climate. Changes in dissolved oxygen in the Pacific basin and its relation to changing ocean circulation have also been investigated. A new finding is that the shallow meridional overturning circulation in the Pacific has rebounded to levels not seen since before 1976-77. Decadal trends and variations in water mass anomalies in the tropical and subtropical thermocline in the tropical Atlantic have also been investigated as well as the communication between the subtropical and tropical Atlantic through ocean currents

and its connection with the global thermohaline circulation as it passes through the Tropical Atlantic.

- **Coupled atmosphere-ocean modeling.** A coupled ocean-atmosphere general circulation model comprised of the (NCAR Community Climate Model, Version 3 [CCM3] and the Miami Isopycnal Ocean Model--MICOM), has been developed and used to produce a 500 year simulation of decadal variability in the tropical oceans. Both coupled and uncoupled ocean only model simulations were analyzed to test hypotheses and results inferred from observations. The mechanisms connecting the subtropical subduction zones and the equatorial ocean via the Subtropical Overturning Circulations (STC) and the role of STCs on long-term climate variability in the equatorial Pacific were investigated. Observations have been compared with the CCM3 MICOM model simulation and NCAR coupled model (CCSM) results to assess the model performance in the North Pacific, in particular in terms of sea surface salinity and mixed layer depth biases and resulting implications for climate prediction. Cheng is also the principal analyst in a study analyzing an eddy resolving N. Pacific simulation using the HYCOM model (Hybrid Coordinate Ocean Model) and altimeter data from Topex/Poseidon. This model will be used to study the heat budget in the Kuroshio Extension and its relationship to surface forcing as well as lateral heat transport by the ocean.

Goal 5: To document the diurnal cycle of rainfall and surface salinity on the basis of moored buoy measurements in the tropical oceans.

Accomplishments:

- **Rainfall.** An analysis of the diurnal cycle in tropical rainfall over open ocean regions using moored buoy self-siphoning rain gauge data has been completed. The analysis indicates the tendency for an early morning maximum, followed by a secondary maximum in the afternoon. Superimposed upon this overall pattern, there is significant regional and seasonal variability. These results have been compared with those of previous studies of short-term tropical rainfall variability. Some significant discrepancies with recent satellite studies have been pointed out and discussed. This study also provides a baseline for future studies with the buoy rainfall data.

- **Surface salinity.** An analysis of the effect of the diurnal cycle in fresh water forcing on surface salinity variability and upper-ocean mixing processes is nearing completion. The surface buoyancy flux, corresponding to the heat and fresh water fluxes measured at the buoys, indicates negative (stable) values during the day and positive (unstable) values at night. Thus the overnight cooling of the surface water overwhelms any negative stability related to the early morning maximum in rainfall. The corresponding diurnal cycle in surface salinity at the buoys has a maximum in the early morning and a minimum in the afternoon. It has been found that this variability is primarily a function of wind speed, with a tendency for the largest diurnal amplitudes to occur during low wind conditions when turbulent mixing is a minimum.

Goal 6: To investigate the role of the atmospheric boundary layer and upper-ocean in maintaining east Pacific synoptic scale disturbances.

Accomplishments:

- **Using TAO buoy data, together with a regional model, to study boundary layer processes.** Westward propagating synoptic scale disturbances, commonly named African waves or easterly waves, are the primary source of hurricanes in both the Atlantic and east Pacific. The origin of these disturbances in the eastern Pacific is not well understood. The convection coupled to these waves is known to be important for maintaining the initial efforts that have focused on the role that warm sea surface temperatures and unstable boundary layers in the east Pacific intertropical convergence zone region play in coupling convection to synoptic scale waves.

Goal 7: To better understand the morphology of Indian monsoon rainfall and its relationship to Indian Ocean sea surface temperature.

Accomplishments

- **Relating Indian monsoon rainfall indices to sea surface temperature.** Various indices of rainfall over the Indian subcontinent were related to Indian Ocean sea surface temperature. Regional indices describing rainfall anomalies in the west and central/east regions of India exhibit stronger relationships with Indian Ocean sea surface temperature variability than all India rainfall. The main region of near-equatorial SST variability to which the monsoon rainfall is coupled is south of the equator, where the thermocline and mixed layer are shallowest. The Indian Ocean is quite different from the Pacific Ocean in this respect, because it does not have persistent equatorial upwelling, as is found in the Pacific.

- **Categorizing the subseasonal variability of monsoon rainfall.** Southwest Monsoon rainfall breaks have been shown to be strongly related to subseasonal variability in the Bay of Bengal, involving a local coupled air-sea interaction process. Southwest monsoon break variability has been attributed to the MJO, but the processes involved here appear to be distinct from it.

- **Categorizing subseasonal sea surface temperature variability.** A new mode of summer subseasonal SST variability has been identified in the southern hemisphere, which involves the Indian Ocean. Plausible physical mechanisms have been proposed to account for its existence.

Long-term measurements of oceanic rainfall using underwater sound

Task III: J. Nystuen, PI)

Goal: To demonstrate the feasibility of making rainfall measurements at sea based on acoustics.

Accomplishments:

- Ambient sound measurements were made on NOAA TAO moorings in the Eastern Tropical Pacific Ocean at 8, 10 and 12 N, along 95 W during 1999-2003. The period over which the measurements were taken includes the EPIC field program period in September 2001. These measurements demonstrate the acoustic detection and measurement of rainfall at sea. Comparisons with ancillary rainfall measurements show promising agreement.

Low-Latitude Cloud Feedbacks on Climate Sensitivity

(Task III: C. S. Bretherton, PI, M. Wyant)

Goal 1: To contribute to the coordination of Cloud Process Team (CPT) activities.

Accomplishments:

- **Organizing team meetings.** Coordinated an initial CPT group meeting on 20-21 November 2003 at NCAR, with approximately 35 participants including all the funded CPT investigators and all but two advisory group members. Team members include NOAA/GFDL, NCAR, and NASA Global Modeling and Assimilation office (GMAO). A series of talks and discussions led to the formation of three focus groups on the formulation of subgrid microphysical and radiative processes, boundary layer clouds, and deep tropical convection, specification of column locations for column oriented analyses, and discussion of PI tasks.

- **Setting up a CPT web page (***www.atmos.washington.edu/~breth/CPT-clouds.html*) to provide general information about the CPT project and a password-protected CPT web page for exchange of results and information.

- **Coordinating a model archive** on NCAR's mass store including control and perturbed-climate simulations using recent versions from all three participating modeling centers, with access instructions on the CPT web page.

- **Hiring an NCAR liaison scientist.**

Goal 2: To compare simulations of tropical clouds in different climate models.

Accomplishments:

- **Comparing model simulations of clouds.** A full-time research scientist hired to work with the principal investigator has analyzed how the tropical clouds simulated by the three models respond to climate perturbations using a dynamical binning scheme based on monthly mean 500 mb vertical velocity that naturally distinguishes between deep convective and subsidence regimes of the tropics. The three models have dramatically

different longwave and shortwave cloud forcing changes to tropical warming, and that their responses are significantly dependent on the geographic pattern of warming. The NCAR, GFDL, and NASA/GMAO have substantially different vertical distributions of cloud in different tropical climate regimes. The NCAR model has much more supercooled liquid water and substantial cloud very close to the sea-surface, compared to the GFDL model. ISCCP data suggest reality lies somewhere in between these models. The three models also have different cloud responses to climate change, even though the NCAR and GFDL models have similar climate sensitivities. The GMAO model has a very strong positive cloud feedback on climate warming.

- **Simulating the Walker Circulation**. Work is underway to produce a set of model simulations of an idealized tropical Walker circulation over a mixed layer ocean, run to a radiative-convective steady state with and without doubled CO2.

Goal 4: To improve the simulation of clouds in the NCAR Climate System Model

Accomplishments:

- **Improving the NCAR Climate System Model:** specifically the representation of subgrid cloud microphysical, moist convective and radiation processes. This project is being undertaken in coordination with the Community Climate System Model and the Atmospheric Model Working Group.

Arctic Climate Change

(Task II: J. Overland, PI, **N. Bond, K. Wood, S. Rodionov, M. Wang**)

Goal 1: To place the recent warming of the Arctic in terms of a historical context.

Accomplishments:

- **Resurrecting 19th century observations.** Historical records from explorations and surveys carried out in the 19th century have been examined to describe how sea-ice extent during that era compares with that during recent decades. The data assembled thus far suggest that the retreat of sea-ice since the late 19th century may not be as dramatic as widely believed.

- **Analyzing mid-20th century surface air temperature data.** It has been found that the recent warming of surface air temperature over the Arctic is especially pronounced during spring, and that it was much braoder in spatial extent than the warming that took place during the 1920s and 1930s.

Goal 2: To understand the mechanisms responsible for recent environmental change in the Arctic.

Accomplishments:

- **Retreat of tundra**. Analysis of NDVI data has revealed a pronounced retreat of Arctic tundra, particularly over regions of Alaska and Canada. A strong correspondence has been demonstrated between the regions in which the tundra has retreated and regions in which midsummer surface air temperatures have climbed above 10° C.

- **Warming of the Bering and Beaufort Seas.** An analysis of sea surface temperatures over the Bering and Beaufort Seas shows substantial warming during the past decade. Analysis of the ocean heat budget indicates that this warming is due primarily to the advection of warmer water from lower latitudes rather than to changes in the local radiative balance, as would be the case if it were simply a manifestation of greenhouse warming.

- **Gulf of Alaska.** A comprehensive review of the meteorology and oceanography of the northern Gulf of Alaska was published. *[113]*[2] An analysis of atmospheric and oceanic conditions over the last decade has revealed that a major change that occurred around 1998 differs in character from the other major changes of the last 50 years.

Monitoring the Eurasian Basin of the Arctic Ocean

(Task III: I. Rigor PI**,** J.M. Wallace)

Goal 1: To deploy drifting buoys (2 per year) in the Eurasian Basin of the Arctic Ocean which monitors surface meteorological, sea ice, and ocean conditions which affect the mass balance of sea ice.

Accomplishments

- **Deployments.** Five buoys have been deployed since September 2003, and 3 more have been purchased and are ready for deployment.

Goal 2: To explain the large extent of open water in the Arctic off the coast of Alaska during recent summers.

Accomplishments:

- **Ice model.** A simple model was constructed that uses the observed drift of sea ice (buoys) to estimate the age of sea ice drifting on the Arctic Ocean. Experiments with this model indicate that the decline in Arctic sea ice extent during recent summers may be interpreted as a delayed response to changing surface wind patterns over the Arctic over the past 15 years. This model shows that most of the older, thicker sea ice was flushed out of the Arctic Ocean and into the North Atlantic Ocean, following the "regime shift" in the Arctic Oscillation in 1989, leaving the Arctic with younger, thinner ice that is more prone to melt away during summer. In recent summers, thin ice, formed along the Eurasian coast the previous autumn, has been drifting into the coastal region north of Alaska and melting. The age (thickness) of sea ice explains over 50% of the year-to-year variability in summer sea ice extent in the Arctic.

[2] Bracketed number refers to a publication associated with the project that are listed at the end of this report.

Model Output Analysis for Designing a Long Term Observing System for Ice Thickness

(Task III: R. Lindsay, PI)

Goal: To use model-based simulations of the sea ice thickness to help guide the selection of the optimal locations in which to deploy moorings with upward looking sonars that measure ice thickness.

Accomplishments:

- **Choosing representative locations.** Locations have been identified that are well correlated with the basin-wide mean ice thickness. Simulations, based on 56 years of retrospective analysis, indicate that the North Pole is a suitable site for the first measurement system and, given the existence of measurements at the North Pole, a second site in the Chukchi Sea would do most to improve the basin-wide mean ice thickness estimates.

- **Representing the dominant patterns of variability.** The model was used to determine the locations that best identify the major modes of spatial variability of the annual mean thickness. This was accomplished with empirical orthogonal functions and additional locations were determined that would best complement the two existing measurement sites at the North Pole and in the Chukchi Sea.

- **Implementing the sampling strategy.** The North Pole site was established by the UW/APL Polar Science Center through NSF funding and the Chukchi Sea site was established by NOAA.

Correction of Systematic Errors in TOVS Radiances over the Arctic

(Task III: Jennifer Francis, Rutgers, PI; Axel Schweiger, UW; Tony Reale, NOAA-NESDIS).

Goal: To identify, quantify, and mitigate errors caused by changes to satellite orbits, instruments, and/or calibration method and ultimately to produce a record of TOVS radiances and retrieved products from 1979 onward that minimizes known errors.

Accomplishments:

- Compiled a large collection of radiosondes previously not available through the GTS system with a significant Arctic coverage.
- Compiled a global TOVS Level-1b data sets for HIRS and MSU.
- Assembled a suite of radiative transfer models for intercomparison to identify RT model biases.
- Investigated TOVS retrieved cloud trends over the Arctic seas and compared with other satellite retrievals and surface observations.

Fresh-Water Dynamics Connecting The Arctic and Atlantic

(Task III: P. Rhines, PI)

Goal: To assess the interaction between Arctic and Atlantic regions, using observations and laboratory simulations.

Accomplishments:

- Analyzed oceanic transport of volume, heat and fresh-water through Davis Strait, west of Greenland.
- Analyzed current meter mooring observations on the Labrador Slope
- Analyzed the subpolar Atlantic circulation using Topex/Poseidon satellite altimetry, together with our mooring observations of circulation, and ship-based hydrography.
- Analyzed observations and laboratory simulations of the polar atmospheric circulation, under the influence of mountainous continents.

Ocean Climate Observations West of Greenland.

(Task III: P. Rhines, PI)

Goal 1: To support the deployment of an acoustic-Doppler current profiler in Barrow Strait, as part of the International Arctic-Subarctic Ocean Flux (ASOF) monitoring of Arctic outflows.

Accomplishment:

- The deployments were carried out as planned in summer of 2003.

Goal 2 : To support field work in the Labrador Sea, making use of "Seagliders".

Accomplishments:

- **Two Seagliders were successfully launched** 100km offshore of Nuuk, Greenland, in October 2003. These autonomous undersea vehicles carried out hydrographic sections totaling about 4000 km in length, making 1550 hydrographic vertical profiles from surface to 1000m depth, during 4 months of winter. It was a dramatic success, the first such deep ocean deployment of this new instrument vehicle. The Seagliders were built using funds from NOAA and from support from the Office of Naval Research, who have subsequently ended their funding of the project after seeing it through many years of development. A poster describing the Seaglider expedition can be viewed at *http://www.ocean.washington.edu/research/gfd/Seaglider-poster-iva.pdf*

Center for Science in the Earth System

(Task III: E. Sarachik PI, D. Battisti, J.M. Wallace, I. Kamenkovich, R Morss, **T.P. Mitchell, *W. Roberts, K. Takahashi, J. Booth***)

Goal 1: To investigate the role of the Southern Ocean in climate variability and change.

Accomplishments:

- **Evaluating the role of surface wind stress in ocean variability.** A study has been completed of the role of the day-to-day variability of the wind stress at the air-sea interface the Southern Ocean. It was found that daily fluctuations in the surface wind stress reduce summer-time stratification in the upper ocean and deepen the mixed layer. Daily variability in the air temperature and humidity plays a secondary role. Daily fluctuations in the surface wind also explain a major part of high-frequency variability in the ocean temperature in the uppermost 50 meters.

- **Investigating the dynamics of water masses in the Southern Ocean.** The role of the Antarctic Intermediate Water in affecting the stratification in the tropical Pacific is currently being investigated, and a plan is being developed to study the interaction of the Antarctic Bottom Water with rough topography in the Atlantic and Pacific.

Goal 2: To determine the degree to which it is essential to resolve mesoscale eddies in the ocean models used in climatic research.

Accomplishments:

- The effects of **mesoscale eddies** on climate variability and their role in distributing heat, salt and chemical tracers are being investigated. Preliminary results show several important differences between mean circulations in eddy-resolving and non-eddy-resolving numerical simulations.

Goal 3: To advance the state of the art of statistical prediction of ENSO.

Accomplishments

- Using **linear inverse modeling** techniques, a model with comparable skill to current operational dynamical ENSO models was developed. By decomposing this model into its Principal Oscillation Patterns it was found that the decay time of the linear ENSO mode is longer than previously believed, although highly dependent upon the dataset used. Most of the skill in predicting the state of ENSO lay in the evolution of this one mode.

Goal 4: To improve the understanding of the annual cycle of the sea surface temperature in the southeast tropical Pacific.

Accomplishments

- Estimating the advective terms in the heat content budget in the Peru Current region.
- Estimating the net surface heat fluxes as residual from the budget calculations and comparing them with the COADS climatology from Southhampton Oceanographic Center, which proved to be favorable.
- Performing harmonic analysis of the budget terms and diagnosis of their relative importance in producing the annual cycle in heat content.

Goal 5: To reassess whether El Niño events are becoming more frequent and more intense, as reported in the Third Assessment Report of the IPCC.

Accomplishments

- The apparent shift of tropical climate toward the warm phase of the ENSO cycle as reported in the Third Annual Assessment Report of the IPCC is less prominent when data for the past decade are taken into account. The findings cited by the IPCC were largely based on the Darwin sea-level pressure record. The observed trends in the Arctic and Antarctic Oscillations towards their high index polarities have contributed to the rise in sea-level pressure at Darwin over the past 50-years. When these contributions are taken into account, the evidence of a "regime shift" toward the warm polarity of the ENSO cycle is less compelling.

Goal 6: To explore the relative priorities of various kinds of observations with respect to the prediction of ENSO.

Accomplishments:

- Observing system simulation experiments were conducted using a linear, stochastically forced ENSO model. Forecast simulations were carried out for a number of observing network configurations, and forecast skill was compared based on averages over 1000 years of
  simulated ENSO events. It was found that subsurface ocean observations are relatively unimportant for ENSO prediction when good information about sea surface temperature (SST) is available; adding subsurface observations primarily improves forecasts initialized in late summer. For forecasts longer than a few months, the most important region for observations is the eastern equatorial Pacific, south of the equator; a secondary region of importance is the western equatorial Pacific. The results demonstrate that several decades of data are sufficient for comparing the relative effectiveness of different observing networks in the context of ENSO prediction.

Goal 7: To make widely used datasets more readily available to the research community.

Accomplishments

- **Improving the data archive.** JISAO's web-based data archive is being incorporated into the CSES web-based data archive. Some of the less widely used time series that were formerly offered will no longer be available, while Pacific Northwest glacier time series and extensive hydrological datasets are being added. Live Access Server software that will enable users to make simple pictures and subset gridded data sets on the WWW is being added. The archive is being restructured in such a way as to enable remote local and remote users to ingest JISAO datasets within MATLAB, GrADS, and Ferret software, and through the NOAA Climate Diagnostics Center's compositing web page.

- **Expanding utility of NCEP-NCAR Reanalyses.** Five-day mean and covariance quantities have been computed from the NCEP-NCAR daily reanalyses, suitable for use in investigations of intraseasonal climate variability.

- **Incorporating new datasets.** Gridded fields of marine chlorophyll and aerosols based on satellite remote sensing have been added to the archive.

An Experimental Hydrologic Forecasting System

(Task III: D. Lettenmaier PI, E. Wood)

Goal 1: To expand NOAA's hydrological prediction capability.

Accomplishments:

- **Expanding the domain.** The real-time monthly to seasonal hydrologic forecasting system that was implemented as a pilot project during winter 2002-03 for the Pacific Northwest has been expanded to the western U.S. domain. Additional streamflow forecast locations in California were activated, and additional locations in the Colorado and upper Rio Grande River basins and the Great Basin are under development. Forecasts extending six months to a year are produced monthly, using both Extended Streamflow Prediction and climate model-based approaches.

- **Augmenting the data set.** The real-time index station dataset used to drive the spin-up simulation of initial conditions was expanded first from 21 to 102 stations, and then to 280 stations; and the snow water equivalent (SWE) observation station network used to adjust the initial forecast state (a one-time assimilation each forecast cycle) was extended to include a greater number of stations in Canada (which are important for Columbia River Basin forecasts).

- **Upgrading the model.** The system was upgraded to run a newer version of the VIC hydrologic model, which required recreating a suite of ancillary datasets used for interpreting the forecasts.

- **Expanding the suite of products.** Forecast and nowcast products were expanded to include spatial plots of temperature, precipitation, runoff, soil moisture and SWE values, anomalies and percentiles.

- **Incorporating ensemble forecasts.** NSIPP-1 ensemble forecasts were added to the climate model-based forecasting approach, which previously included the ensembles from NCEP Global Spectral Model (GSM). A retrospective analysis comparing the skill of GSM and ESP-based forecasts is now in review for publication in the *Journal of Geophysical Research*.

- **Upgrading the distribution system.** The web site for distribution of forecasts has evolved to reflect the additional components. It can be viewed at *http://www.hydro.washington.edu/Lettenmaier/Projects/fcst/*

Climate Assessments for the Pacific Northwest

(Task III: E. Miles, PI; D. Fluharty, R. Francis, D. Lettenmaier, R. Palmer, D. Peterson, A. Hamlet, R. Leung, **N. Mantua**, **P. Mote**, R. Norheim, D. Reading, **E. Salathé**, R. Slaughter, **A. Snover**, L. **Whitely-Binder**, ***V. Agostini, M. Andersen, A. Ball, J. Littell, S. Morlock, B. Trask, N. Van Rheenan***)

Goal 1: To extend the past record of climate variability over the Pacific Northwest, using proxy data.

Accomplishments

- **Identifying controls.** Work was completed on the identification of atmospheric, climatic and ecological controls on extreme wildfire years in the northwestern United States, as discussed in [43].
- **Developing runoff reconstruction**. A paleo-reconstruction for Columbia Basin runoff and drought since 1750 was developed and presented in [44].
- **Investigating clam growth rings**. It has been demonstrated that growth rings in long-lived geoducks clams can provide a new and very promising tool for paleoclimate reconstructions for coastal ocean temperatures in the extratropical North Pacific. Individual geoducks clams can live at least 150 years. An abundant supply of preserved clamshells and cross-dating techniques can be used to extend growth series for at least several centuries into the past, and geoducks clams are distributed in coastal waters from San Francisco, CA, north to Alaska, and southwestward to Japan. The details of the analysis are reported in [115].

Goal 2: To assess the sensitivity of Pacific Northwest resources to greenhouse warming.

Accomplishments

- **Estimating regional climate sensitivity.** The impacts of year-to-year and decade-to-decade climatic variations on some of the Pacific Northwest's key resources are used as a basis for estimating the sensitivity of regional climate changes that are to occur in association with expected human-induced global warming. These sensitivities are then linked to scenarios of future climate produced by IPCC model simulations to yield climate change impacts scenarios for the Pacific Northwest. Details are reported in [96].

Goal 3: To make weather and climate forecast information more readily available to resource managers in the Pacific Northwest.

Accomplishments

- **Developing a website.** A website has been developed that allows users to extend NOAA/NCEP 7-14 day lead time ensemble forecasts for the indices of prominent circulation patterns into experimental (7-14 day lead time) extreme weather event risk assessment forecasts. The forecasts are based on observed relationships between the probability of certain extreme weather events in the US and variations in the Pacific North American (PNA) and Northern Annual Mode (NAM) patterns. The url for the

JISAO/CIG experimental risk-assessment page is:
http://www.cses.washington.edu/cig/fpt/extreme.shtml

- **Examining river runoff**. The variability and potential predictability in North American river runoff was assessed and results are reported in [84].

Capacity Building in Coastal Communities in Southern Africa

(Vlad Kaczynski, PI**)**

Goal: To help coastal communities in the Republic of South Africa, Namibia and Mozambique to adapt to changing climate and marine environmental conditions.

Accomplishments:

- Designed and organized the **Regional Capacity Building and Coastal Adaptation Seminar** at the University of Port Elizabeth, Republic of South Africa in July 2004. This 6-working day seminar and round table discussion contributed to a greater capacity in adaptation processes of coastal communities of South Africa, Namibia and Mozambique to the ocean and coastal life conditions and to the use of natural resources that are potentially available but threatened by unsustainable exploitation. Over 40 foreign and Southern African specialists delivered presentations on marine environmental and sea/coastal resource management, coastal development planning, policy aspects, enabling environment for improved social and economic responses to the ocean climate change, roles of non-governmental organizations, and opportunities for business including small and micro enterprises for the coastal poor. The Seminar attracted over 140 participants.

- Designed and organized the **Public Education Expo**: "Marine Resources in Service of Coastal Communities", University of Port Elizabeth, July 2004. This event was organized at the same time as the Regional Capacity Building Seminar and was based on the mobile exhibition package delivered and organized by NOAA - Office of Global Programs. The Expo explained key ocean climate, physical, chemical, and biological changes in the marine and coastal environments and delivered timely warning of the impacts of natural phenomena like El Niño Southern Oscillation and other climatic changes (including those caused by humans) might have on the well being of coastal populations and their economies. There were over 2,000 visitors who received verbal presentations, guidance, brochures and other written materials.

Environmental Chemistry

The Carbon Cycle

(Task II: R. Feely, C. Sabine, **C. Cosca, F. Menzia**) (Carbon Cycle References: 30, 31, 34, 35, 36, 104, 107, 108, 109, 110, 117)

The PMEL/JISAO Global Carbon Cycle Program (GCCP) conducts research on the sources and sinks of carbon dioxide in the oceans. Atmospheric and oceanic carbon dioxide data are collected on cruises onboard NOAA vessels and from the TAO moorings. Modeling studies employing

these data enhance our understanding of the ocean's role in the global carbon cycle and the important feedback mechanisms that will affect future climate changes. The following summarizes several of the GCCP's successes, including promising developments in new research.

Goal 1: To contribute to our scientific understanding of carbon sources and sinks in the oceans.

Accomplishments:

- **Determining anthropogenic CO_2 in the world oceans.** The GCCP provided an estimate of the amount of anthropogenic CO_2 in the World Oceans based on observations from the WOCE/JGOFS/OACES Global CO_2 survey. The integrated amount of anthropogenic CO_2 that has accumulated in the oceans between 1800 and 1994 is estimated to be 118 ± 19 Pg C, which is approximately 48 % of the total amount of fossil fuel and cement manufacturing CO_2 emissions during this period. These results suggest that the terrestrial biosphere was a net CO_2 source to the atmosphere of 39 ± 28 Pg C over this timeframe. The highest inventories are associated with the Subtropical Convergence zones. Low inventories are observed in the equatorial and high latitude Southern Ocean regions. [34]

- **Estimating the carbonate dissolution in the world oceans.** The GCCP used total alkalinity together with ^{14}C and CFC data to estimate $CaCO_3$ dissolution rates in the World Oceans. These rates are important for predicting how fast the oceans can neutralize the anthropogenic CO_2. The integrated rate of dissolution for the global ocean is approximately 0.5 Pg C yr^{-1}. The penetration of anthropogenic CO_2 into the ocean interior has caused an upward migration of the calcite and aragonite saturation horizons by about 40 - 200 m over large regions of the Pacific and Indian Oceans. Over time, these changes in the aragonite saturation state will have profound impacts on the health of our coral reefs and other $CaCO_3$ shell-forming organisms. [109]

- **Determining the effects of the Pacific Decadal Oscillation on seawater pCO_2 in the equatorial Pacific.** The equatorial Pacific Ocean is one of the most important yet highly variable oceanic source areas for atmospheric carbon dioxide (CO_2). We used the partial pressure of CO_2 (PCO_2), measured in surface waters from 1979 through early 2001, to examine the effect of the Pacific Decadal Oscillation phase shift, which occurred around 1988 to 1992, on the equatorial Pacific CO_2 chemistry. In the decade before the shift, the surface water PCO_2 (corrected for temperature changes and atmospheric CO_2 uptake) in the central and western equatorial Pacific decreased at a mean rate of about 2 µatm per year. After the shift, surface water PCO_2 increased at about 1.5 µatm per year. These changes altered the CO_2 fluxes of the equatorial Pacific significantly. [117]

Goal 2: To foster the use of chemical and hydrographic data information for modeling efforts

Accomplishments:

- **Distributing ocean carbon data to the oceanographic community.** The GCCP group has developed a WWW-based access for hydrographic and carbon data. This resource has been used by the modeling community to verify their carbon system biogeochemical process models for the oceans. The WWW site is supported by a live access server that provides both data access and graphical outputs. All the data and graphics can be found at the following WWW site: *http://www.pmel.noaa.gov/co2/co2-home.html*

- **Integrating historical PMEL carbon data with other data sets.** The GCCP group has formed a partnership with CDIAC to provide data products from the Repeat Hydrography CO_2/Tracer Program and the WOCE/JGOFS/OACES Global CO_2 Survey**.** These products can be found at: *http://cdiac.ornl.gov/oceans/glodap/Glodap_home.htm*

Goal 3: To contribute to graduate education at the University of Washington.

Accomplishment:

- **Hosting North Pacific Climate Variability Workshop.** The GCCP Group hosted a workshop on the variability of the North Pacific carbon system in June. The focus of the workshop was on an overall picture of North Pacific variability that draws together all of these individual lines of evidence and looks for coherent patterns that may help us understand the regional significance of this variability and the possible mechanisms controlling the observed spatial and temporal patterns. The workshop was designed to bring together relevant data sets for re-analysis with a view toward the larger picture. This data synthesis will be further enhanced by a simultaneous examination of North Pacific variability in a variety of climate model runs. The workshop was a component of the University of Washington Program on Climate Change so that both students and faculty members directly contributed to and benefited from the workshop.

Chlorofluorocarbon Tracer Program

(Task II: J. Bullister, **R. Sonnerup, F. Menzia)**

Goal 1: To monitor the uptake of anthropogenic chlorofluorocarbons (CFCs) into the ocean on decadal timescales and to use this information to estimate the rates and pathways of ocean ventilation processes.

Accomplishments:

- Participated in several CLIVAR Repeat Hydrographic/CO_2/Tracer expeditions in the Atlantic and Pacific oceans, repeating sections occupied a decade earlier. The goal of this program is a systematic and global re-occupation of select hydrographic sections to quantify changes in storage and transport of heat, fresh water, CO_2, CFCs and related parameters. Changes in observed CFC fields are being used to estimate water mass formation rates and to evaluate the importance of physical vs. biological processes in observed subsurface dissolved oxygen changes.

- Developed analytical methods for ultra-trace level measurements of sulfur hexafluoride in seawater. This anthropogenic compound is rapidly increasing in the atmosphere and

has the potential to provide valuable information on the rate of uptake of gases in the ocean and for estimating water mass ventilation rates.

Goal 2: To use observed CFC tracer fields to help evaluate global ocean model simulations and to estimate the oceanic uptake of other tracer gases, including carbon dioxide.

Accomplishments:

- Completed estimate of the global uptake of CFCs in the ocean through the 1990's. This inventory will be of value for testing global models of oceanic uptake of trace gases.

- Worked with carbon investigators to utilize CFCs to estimate the global oceanic uptake of anthropogenic carbon dioxide.

Carbon Isotope Constraints on Ocean GCM Simulations of Anthropogenic CO_2 uptake

(Task III: P. Quay, PI, **R. Sonnerup**)

Goal: To use observed data on the isotope ^{13}C as a basis for optimizing the mixing scheme in the GFDL Modular Ocean Model.

Accomplishments:

- A $^{13}CO_2$ gas exchange and biological cycling module for the GFDL Modular Ocean Model was implemented and used to simulate the steady state pre-industrial concentration of $DI^{13}C$, using several representations of mixing in the model.

- The same variants of the model were used to estimate the oceanic response to the observed anthropogenic CO_2 and $^{13}CO_2$ perturbations.

- CO_2 and $^{13}CO_2$ changes in the Indian Ocean derived from the different variants of the model were compared with the observed changes. The variant of the model that compares most favorably with the observations arguably possesses the most realistic representation of the mixing.

Aerosols and Trace Gases

(Task II: Bates P. Quinn, D. Covert, **D. Coffman, *S.* Doherty, D. Hamilton, J. Johnson, T. Miller, K. Schulz)**

The PMEL/JISAO Atmospheric Chemistry - Aerosol Program is designed to quantify the spatial and temporal distribution of natural and anthropogenic atmospheric aerosol particles and to determine the physical, meteorological and biogeochemical processes controlling their formation, evolution and properties. Recent efforts are grouped under three goals:

Goal 1 – To assess the regional climate and air quality impacts of atmospheric aerosol particles through measurements of their chemical and radiative properties

Accomplishments:

- **Carrying out field measurements.** Aerosols directly affect climate and air quality through the scattering and absorption of incoming solar radiation. Measurements of aerosol properties during integrated field campaigns provided data for the validation of regional models that are used to estimate aerosol direct radiative forcing and the validation of algorithms used to retrieve aerosol optical depth from satellite observations. In addition, the measurement of regional aerosol plumes allowed for the linking of aerosol sources to climate and air quality impacts. The overall payoff is a reduction in the uncertainty associated with estimates of aerosol direct radiative forcing (climate) and aerosol haze plumes (air quality).

- **Synthesizing measurements from different field campaigns.** Means and variability of aerosol chemical composition and optical properties were compared during the past year [106] for the first and second Aerosol Characterization Experiments (ACE 1 and ACE 2), a cruise across the Atlantic (Aerosols99), the Indian Ocean Experiment (INDOEX), the Asian Aerosol Characterization Experiment (ACE Asia), the Tropospheric Aerosol Radiative Forcing Observational Experiment (TARFOX), and the New England Air Quality Study (NEAQS). The data have allowed us to draw several conclusions about the chemical and optical properties of aerosols in the marine boundary layer as well as to identify some of the gaps in our understanding.

- **Analyzing measurements over New England.** A more thorough analysis of the data from NEAQS 2002 revealed that on average, 75 ± 8% of the dry aerosol mass sampled 18 m above the sea surface was in the < 1 μm fraction (size cut at 55% relative humidity). The major sub-micron aerosol components were ammonium sulfate and particulate organic matter comprising more that 89% of the total mass. Under northwesterly flow, Particulate Organic Matter was the dominant component (67%) followed by $(NH_4)_xH_ySO_4$ (23%), dust (7%), and EC (3%). Under southwesterly, $(NH_4)_xH_ySO_4$ was the dominant component (55%) followed by particulate organic matter (40%), dust (3%) and EC (2%). Multiple linear regressions of submicron non-refractory (NR) particulate organic matter and NR $(NH_4)_xH_ySO_4$ versus submicron light scattering (σsp) at 500nm wavelength suggest that particulate organic matter was the dominant chemical component contributing to aerosol light scattering (haze) during NEAQS 2002, contributing 69% and 58% to σsp (measured at 55% relative humidity) in the northwesterly and southwesterly trajectories, respectively. These data are similar to that found off the mid-Atlantic states during TARFOX but contrary to the current understanding that the New England haze is primarily a result of sulfate aerosol.

Goal 2: To quantify the oceanic source of atmospheric sulfur, dimethylsulfide.

Dimethylsulfide (DMS) is biologically produced in the surface ocean and is the major natural source of sulfur to the atmosphere. In the atmosphere, DMS is transformed into sulfate aerosol particles which scatter solar radiation back to space and alter the properties and lifetimes of clouds. The concentration of DMS in surface seawater and thus its flux to the atmosphere vary

spatially and temporally as a result of the physical, biological and chemical properties of seawater.

Accomplishments:

- **Establishing a database.** PMEL-JISAO scientists are developing and maintaining a web-based interactive database containing over 30,000 measurements of surface seawater DMS concentrations that have been collected since the early 1980s. The database (*http://saga.pmel.noaa.gov/dms/*) now contains over 30,000 seawater DMS measurements.

- **Collecting additional data.** Additional measurements of surface seawater DMS concentrations are needed to assess the temporal and spatial variability, particularly in higher latitudes. The automated PMEL underway-DMS system operated onboard the NOAA R/V Ronald H. Brown data can be viewed in near real-time at *http://saga.pmel.noaa.gov/underwaydms/*. Users can plot the DMS and auxiliary data collected during various time periods in 2002 and 2003.

Goal 3: To improve our capability to observe, understand, predict, and protect air quality through national and international partnerships.

Accomplishment:

- **Hosting IGAC**. PMEL/JISAO hosts the International Global Atmospheric Chemistry (IGAC) Core Project Office with funding from NOAA, NSF and NASA. The goal of IGAC is to promote and facilitate international atmospheric chemistry research that will lead to a better understanding of the Earth System. Dr. Sarah Doherty, JISAO Research Scientist, is the Executive Officer of the Seattle Project Office (*http://www.igac.noaa.gov/*). Dr. Tim Bates, PMEL Research Chemist, is a co-chair of the IGAC Scientific Steering Committee. During the past year IGAC has organized 3 international specialty workshops and has initiated 4 new international Research projects.

Atmospheric chemistry and biogeochemistry of methane, and molecular hydrogen

(Task I: **A. Rice**)

Goal 1: To evaluate the seasonal cycle of the concentration and isotopic composition of atmospheric methane To use isotopic constraints to interpret temporal seasonal variations in sources and sinks.

Accomplishments

- **Analyzing measurements.** Measurements of CH_4 concentration and carbon isotopic composition ($\delta^{13}C$) have been ongoing at Niwot Ridge, CO since 1994 and at Montana de Oro, CA since 1996. Measurements of the hydrogen isotopic composition (δD) at these sites were begun in 1998 and 2000 respectively. These long-term datasets were detrended for annual changes in the growth rate, $\delta^{13}C$, and δD over the period and mean values

were subtracted. Residuals were fit with Fourier series to provide a model of the annual average seasonal cycle.

Goal 2: To use isotopic constraints to interpret temporal seasonal variations in sources and sinks.

Accomplishments:

- Applying a simple model. A "sink only", OH-driven CH_4 seasonal cycle was evaluated with the use of a simple "0-dimensional" time dependent model based on chemical kinetics, kinetic isotope effects, and variations in OH fields output from the OSLO 3D CTM. Model output was compared with fits to measured data. Results indicate a strong bias in the seasonal cycle of CH_4, $\delta^{13}C$, and δD, from seasonal sources in the northern hemisphere. Results indicate the presence of a large CH_4 source in early fall providing a peak in CH_4 concentration at that time coincident with unusually depleted $\delta^{13}C$ and δD isotope ratios. The observations suggest the existence of a strong seasonal northern hemispheric biogenic CH_4 source during the early fall, perhaps as a result of rice agriculture or from a "drying-out" of the high-latitude wetlands. The isotopic data also suggests that it is unlikely that this signal is from either fossil CH_4 or from seasonal biomass burning.

Goal 3: To develop and implement a small volume analytical method for measuring the isotopic composition of atmospheric molecular hydrogen.

Accomplishments

- **Streamlining isotopic hydrogen measurements.** Prior work by Quay and Gerst at the University of Washington provided the first high-precision atmospheric isotopic molecular hydrogen (H_2) dataset. However, the method utilized tremendous sample sizes (>1000L) of ambient air and required lengthy analyses. A new method has been developed to streamline these analyses. The new technique uses low temperatures (40K) to isolate atmospheric H_2 and continuous-flow IRMS techniques to measure δD-H_2 in 500ml samples of ambient air. Analysis time has been significantly reduced to roughly one hour per sample. This recently implemented method provides the isotope laboratory with a method to increase sample throughput and dramatically improve the flexibility of air sample collection.

- **Testing the new method.** A comparison of samples (n=30) analyzed using this new method and the more conventional method shows no systematic bias and a level of precision (±3‰) comparable or better than was previously achieved .

- **Analyzing past measurements from Cheeka Peak**. Measurements of δD-H_2 in nearly two dozen catalogued "clean air" samples collected at Cheeka Peak, WA since early 2002 averaged 120±14‰ relative to VSMOW. Average H_2 concentration in these samples was found to be 523±21ppbv. No significant seasonal cycle in either concentration or isotope ratio was apparent. However, more data will be needed to evaluate whether there is significant seasonality in δD.

- **Analyzing global measurements.** Samples collected on board Coast Guard cruises between Seattle and Antarctica during November-December, 2002 and December-March, 2004 were analyzed for δD-H_2. Results indicate a minimum in δD in the equatorial region near 80‰ (vs. VSMOW) corresponding to a maximum in H_2 concentration of ~600ppbv. δD increases poleward to 150‰ in the high latitude southern hemisphere and to 125‰ in the mid-latitude northern hemisphere, mirroring an observed meridional trend in H_2 concentration.

Goal 3: To develop a method for measuring the concentration and isotopic composition of atmospheric formaldehyde.

Measurements of formaldehyde (HCHO) in the atmosphere are revealing gaps in our understanding of the atmospheric chemistry of HCHO and its sources. Studying the isotopic composition of HCHO can improve our understanding of processes which control its concentration, but to date studies are few and limited to the carbon isotopic composition. HCHO also represents 60% of the H_2 total source, but is the only source to remain isotopically uncharacterized.

Accomplishments

- **Developing a new measurement technique.** An innovative method has been developed that has the potential to measure the concentration and both the carbon and hydrogen isotopic composition of HCHO. The analytical technique couples new gas chromatographic methods with recent advances in continuous-flow isotope ratio mass spectrometry. Levels of precision for measurement of concentration and δD-HCHO are approximately ±15% and ±50‰ respectively. Currently, measurements can be made on sample sizes ranging from 19-70 L of air.

- **Analyzing preliminary measurements in urban air.** Measurements of HCHO concentration and δD in samples collected in Seattle, WA during Spring 2004 show considerable variability in concentration (0.44 to 2.9ppbv) and δD (-230 to 210‰ versus VSMOW). These data likely point to a mixture of HCHO sources in this urban environment. There is a clear inverse relationship between concentration and isotope ratio which likely results from a mixture of two dominant HCHO source categories. The most enriched δD values found at low HCHO concentrations are likely dominated by secondary photochemical sources of HCHO, in particular the oxidation of volatile organic compounds. The most depleted δD values found at high HCHO concentrations are likely dominated by primary (direct) sources of HCHO associated with fossil fuel combustion.

- **Extending measurements to clean air sites.** The current focus of this research is to measure δD-HCHO in air samples collected at "clean air" sites, beginning with Cheeka Peak. In remote settings, sources of HCHO should be secondary in nature and dominated by CH_4 oxidation. The characterization of δD-HCHO will provide us with the last source isotope signature in the global H_2 budget.

Marine Ecosystems

Quantitative Analysis of the North Pacific Marine Ecosystem

(Task II: P. Stabeno, J. Overland**,** S. Hickley**,** B**.** Megrey, **N. Bond**, **A. Hermann**, **Y. Lee**, **C. Mordy**, **F. Mueter**, **C. Parada**,**)**

Goal 1: To improve modeling of the North Pacific marine ecosystem.

Accomplishments

- **Developing nested models.** Development continued on a suite of nested physical and biological models designed to serve GLOBEC, Steller Sea Lion Initiative, FOCI, and other programs. Each of the nested physical models is based on the Regional Ocean Modeling System (ROMS), a primitive equation circulation model with highly efficient mixing and advection schemes. These models have been implemented on a distributed memory, massively parallel computing platform at the Forecast Systems Laboratory of NOAA, with generous assistance from their staff. The implementation of parallel code has made it possible to run the model at much finer resolution, and for much longer time periods than was previously possible. Developments toward a multi-scale nested modeling system in the past year included major upgrades of ROMS-based primitive equation models of: the North Pacific at 40 km resolution (NPAC), the NE Pacific (from Baja California through the Bering Sea) at 10 km resolution (NEP), and the Gulf of Alaska at 2.5 km resolution (GOA-2, in collaboration with researchers at the University of Alaska Fairbanks). NEP model hindcasts of years 1997-2001 have been compared with satellite and moored data from the Gulf of Alaska. Models of California at 2.5 km resolution, and the eastern equatorial Pacific at 10 km resolution, have been developed by colleagues, using the output from NEP and NPAC models as boundary conditions. Improvements to the modeling approach in the past year include refinements of bulk formulae for atmospheric forcing, improved methods for lateral input of buoyancy representing river runoff, and corrections to local bathymetry.

- **Incorporating biological processes.** A lower trophic level (NPZ) model with emphasis on juvenile salmon prey items has been fully implemented in three-dimensional form, and driven with nested circulation model output. Prey fields generated from the NPZ model will be used in bioenergetic-based models of salmon, developed with other researchers within GLOBEC. The NPZ model spans the coastal and deep basin areas, and now explicitly includes iron as a limiting nutrient (to better resolve the different dynamics observed in coastal vs. open ocean regions). Output is being used to analyze nutrient flux pathways in the Coastal Gulf of Alaska.

- **Coupling atmosphere and ocean models.** The continuing MEAD program entails coupling an atmospheric model (WRF) with an ocean model (ROMS) across nodes of the Teragrid. A related program, funded by HPCC, entails coupling these models across platforms within NOAA.

- **Modeling walleve Pollock.** Relationships between physical and biological factors that determine the transport and survival of early stages of Pollock in the Gulf of Alaska (up

to age-0 juveniles) to the nursery area (Shumagin Islands) have been investigated using an individual based model coupled to an hydrodynamic (provides current and salinity field) and an ecological (provides the food field for walleye Pollock) model. The setting, optimization, coupling of the models and running of preliminary experiments were the major aim for this period. The individual base model for Pollock and the ecological model (Nitrogen Phytoplankton Zooplankton model) were implemented in a Dec-compac machine. A series of experiments was performed to test the consistency of the code featuring previous runs such as 1994. Also a preliminary sensitivity analysis testing different parameters and the shape of the functions for grazing and predation of the one-dimensional ecological model was performed. In addition, the individual base model was run for a series of 13 years to assess transport of juveniles in the nursery area in the Gulf of Alaska. A Matlab toolbox for visualization of the outputs of both models was developed. Spatial and temporal data of Pseudocalanus (naupliar and copepodites) in Line 8 and of eggs and larvae of walleye Pollock were gathered for validation purposes.

Goal 2: To develop and use quantitative methods to characterize the status of the North Pacific ecosystem and detecting climate change signals.

Accomplishments:

- **Analyzing trends.** A statistical approach was developed to analyze and detect trends in population-based metrics, such as survey catch per unit effort or average individual weight, across large numbers of species. This approach was applied to groundfish communities in the Bering Sea and Gulf of Alaska. It revealed significant trends in catch per unit effort and frequency of occurrence of both commercial and non-commercial fish and invertebrate species in the Eastern Bering Sea.

- **Analyzing covariability in recruitment and survival among Northeast Pacific groundfish stocks.** Combined indices of recruitment and survival rate were developed across major commercial stocks. The combined indices help detect periods of high and low productivity in the groundfish community and appear to be related to large-scale climate patterns. Work on refining measures of uncertainty for the combined indices and on exploring relationships between the indices and environmental variability that could help predict low- and high-productivity periods is ongoing.

- **Analyzing production dynamics.** Surplus production dynamics of the groundfish complexes in the Eastern Bering Sea and Gulf of Alaska were analyzed. Aggregate estimates of biomass from stock assessments and catch data summed across major commercial stocks were used to compute total annual surplus production as an index of overall productivity. Simple statistical models were fit to the total surplus production – total biomass relationship to obtain estimates of maximum sustainable yield for the groundfish complex as a whole.

Goal 3: To assess the performance of the statistical tools currently used to forecast walleye Pollock.

Accomplishment:

- **Comparing the performance of statistical prediction models.** A number of different statistical tools that are commonly used to analyze stock-recruitment data with environmental indices, were applied to simulated data with known properties and apply the analytical tools to the simulated data. The examined statistical tools include traditional linear regression, non-linear regression, generalized additive models, and artificial neural networks. The results indicated that the higher accuracy of the predictive power of non-parametric methods over parametric methods for future recruitment prediction.

Salmon Recruitment and Survival

(Task III: E. Miles, PI, ***V. Agostini,*** R. Francis**, N. Mantua, P. Mote, E. Salathe, A. Snover, L. Whitely-Binder)**

Goal 1: To improve methodology for predicting salmon recruitment.

Accomplishment:

- **Model development.** A relatively simple empirical model has been developed that links three different measures of coastal ocean habitat (sea surface temperature, the date of the spring transition, and coastal sea level) to observed year-to-year variations in coho salmon marine survival. Each year, salmon management agencies predict the expected number of adult coho salmon there are in the ocean before they develop harvest policies, yet pre-season run-size forecasts are notorious for their large errors. Analysis of the model behavior yields a new conceptual model for understanding how highly unpredictable environmental processes influence the ocean survival of coho salmon, and its real-time output from the model offers a relatively simple bases for salmon management personnel to adjust pre-season run-size forecasts using easy to measure environmental data. The details of this study are reported in [77] and a further discussion of the management implications of this work are presented in [79]. A model has also been developed for linking climate to stream impacts on Oregon coho salmon [72].

Goal 2: To assess the risk of extinction of Pacific salmon.

Accomplishments:

- See [39]

Goal 3: To relate decadal variations in salmon recruitment to regime shifts in the marine ecosystem.

Accomplishment:

- Methods for detecting regime shifts in large marine ecosystems have been reviewed [80], and evidence of the occurrence of past regime shifts has been discussed [29].

Air-Sea Interactions on the Bering Sea Shelf

(Task II: **K. Bahl, N. Bond, N. Kachel, C. Ladd, D. Righi, S. Rodionov, M. Spillane,** B. Megrey, J. Napp, J. Overland, P. Stabeno)

Goal – To determine how variations and trends in climate impact the ocean, and ultimately influence the marine ecosystem.

Accomplishments:

- **Analyzing atmospheric forcing of Bering Sea shelf.** Extreme, episodic weather events have been shown to be crucial to changes in populations of a variety of marine species.

- **Maintaining a Bering Sea web site.** Increasing effort has been devoted to providing real-time information on the physical state of the Bering Sea (and to the extent they are available in a timely manner, chemical and biological properties) for use by scientists and fishery managers.

Exploring for Cold-Adapted Microorganisms

(Task III: J. Deming, PI)

Goal: To bring into culture microbes from Arctic settings (especially deep water and around ice) that have previously undiscovered genes and enzymes.

Accomplishments:

- Obtained several specimens on a cruise to the Chukchi Sea in August 2003 aboard the R/V Chinair and performed phylogenetic analysis on them. This work is being carried out in collaboration with Chinese microbiologist Chen Bo.

Ecosystem Indicators for the North Pacific

(Task III, B. Miller, J. Overland and **S. Rodionov**, co-PI's; P. Livingston, S**.** Bartkiw)

The purpose of this project is to add to the suite of ecosystem indicators being provided to the North Pacific Fishery Management Council in the Ecosystem Considerations section of the stock assessment and fishery evaluation document.

Goal 1: Derive ecosystem level indicators for the eastern Bering Sea: K-dominance curves and size diversity spectrum analysis.

Goal 2: Provide a suite of environmental indicators and analysis tools for the Bering Sea.

Accomplishments:

- **Ecosystem indicators:** A size diversity analysis for Bering Sea fish and invertebrates was developed and k-dominance curves were produced.

- **Results presented:** The diversity analysis was presented in the Ecosystem Considerations Section for 2004, which is provided to the North Pacific Fishery Management Council.

Marine Biological Interactions in the North Pacific – Fish Interactions

(Task III: B. Miller, PI; P. Livingston, J. Boldt, K. Dodd, R. Hibpshman, **J. Jurado-Molina**, I. Ortiz, A. Whitehouse)

This research project focuses on improving ecosystem based fishery management through increased understanding of predator/prey relationships, improved predator/prey models, and development of ecosystem indicators.

Goal 1: To investigate the feeding ecology of North Pacific fishes.

Accomplishment:

- **Feeding ecology of North Pacific fishes.** A total of 15,412 groundfish stomachs were analyzed. Personnel contributed to an update of the stomach content analysis procedures manual. Diet summaries and maps were produced for over 105 species/cruise combinations. A tracking system for tracking sample buckets through the system was fully implemented to better track hazardous chemicals and locate particular specimens.

Goal 2: To collect stomach, plankton or benthic samples in the field.

Accomplishment:

- **Assisted with the collection of stomach, plankton or benthic samples.** Collection of groundfish stomachs during the time period totaled 10,264 stomachs. Four cruise legs were covered by JISAO personnel.

Goal 3: To estimate and test parameters of single-species, multi-species and ecosystem models.

Accomplishment:

- **Parameter estimation of ecosystem models,** Modeling activities focused in the updating of the multispecies virtual population (MSVPA) and the multispecies forecasting model (MSFOR). A new quarterly version of the MSFOR was developed. Activities also focused on the development of the multispecies statistical model. The first version of the MSM is finished.

Goal 4: To develop ecosystem indicators.

Accomplishments:

- **Aleutian Islands ecosystem model.** Finished and balanced the food web model for the Aleutian Islands. Compared results between the three Alaskan ecosystem models: Eastern Bering Sea, Gulf of Alaska and Aleutian Islands. Evaluated fishing effort data in the Aleutian Islands.

- **Ecosystem indicators:** Several sections of an Ecosystem Indicators (EI) report were produced as a result of the annual Ecological Indicators meeting at the Alaska Fishery Science Center in Seattle, September 22-23, 2003.

Fish-Marine Mammal Interactions

(Task III: B. Miller, PI; L. Logerwell, D. Gunderson)

Goal: To develop a tag release-recovery model for Pacific cod. The model will be used to understand local-scale and seasonal movements as well as estimating natural mortality rates.

Accomplishments:

- **Literature review:** Literature review on cod (Pacific and Atlantic) biology and mark-recapture methodology. A cod tagging database has been developed which includes current AFSC tagging data (mostly winter) in eastern Bering Sea, previous AFSC tagging data (mostly spring and summer) in eastern Bering Sea, and ADFG tagging data in the Gulf of Alaska.

- **Field data collected:** Assessed pot performance during tidal cycles as a sampling gear for cod abundance estimation. Tagged and released a batch of Pacific cod prior to the beginning of winter fishing season for Pacific cod.

Spatio-temporal Distribution Patterns of Walleye Pollock

(Task III: J. Horne, PI: J. Burgos)

This research is a component of a multi-disciplinary project initiated to examine the effect of varying prey abundance and distribution on Steller sea lion foraging behavior and bioenergetics

Goal 1: To quantitatively describe walleye pollock spatial and temporal distribution patterns.

Accomplishments:

- **Data processing:** Data from 5 NOAA acoustic surveys have been converted to Echoview format and categorized by fish species.

- **Database creation:** Designed and created database of walleye pollock density distributions and aggregation characteristics by transect.

- **School detection sensitivity analysis:** Completed sensitivity analysis of Echoview school detection variables.

Goal 2: To develop a three-dimensional dynamic simulation of walleye pollock abundance patterns.

Accomplishment:

- **Computer simulations:** Initial formulation of computer simulation model was completed. Walleye pollock distributions were created to provide test data for Steller Sea Lion individual based model.

Fisheries Acoustics Research

(Task III: J. Horne, PI)

This project supports an Associate Research Faculty position at the University of Washington, School of Aquatic and Fishery Sciences (SAFS). Research activities examine acoustic backscatter properties of northwest Pacific fish species. Service activities include participation on Midwater Assessment and Conservation Engineering (MACE) survey cruises, liaison between SAFS and the Alaska Fisheries Science Center, organizing and administering the SAFS-AFSC summer internship program, supervision and mentoring of graduate students, acoustic training of students and government scientists, and participation in academic committees at the School of Aquatic and Fishery Sciences.

Goal 1: To examine acoustic backscatter properties of fish.

Goal 2: To increase collaboration between the Alaska Fisheries Science Center and the UW School of Aquatic and Fishery Sciences.

Accomplishments:

- **Courses taught**: Marine BioAcoustics was taught during summer at Friday Harbor Laboratories. Bioacoustical Oceanography was taught during Fall quarter at UW. A module on Fisheries Acoustics was taught for the Techniques in Fisheries class.

- **Papers published:** A total of 10 papers and one book chapter were published. A second book chapter was submitted.

- **Papers presented:** A total of 5 seminars were presented at national and international meetings.

- **Graduate students/Postdocs supervised:** Five graduate students were directly mentored, three postdocs conducted research in association with the laboratory, and the PI participated in an additional 3 student committees.

- **Internship program:** Four undergraduate students participated in the summer internship program. All students had an at-sea experience.

- **Cruise participation:** Acoustic data was collected on a cruise in Japan and over the mid-Atlantic Ridge during the reporting period.

Trends in Fish Abundance and Productivity

(Task III: D. Gunderson, PI; A. Cooper, Gregg, D.Kimura, D. Anderl)

The overall goal of this project is to improve methodology for studying the response of marine ecosystems to the direct and indirect impacts of fishing activities and fluctuations in climate.

Goal: To determine reproductive potential and natural mortality of thornyheads (two species) and Greenland turbot.

Accomplishments:

- Collected ovarian tissue over the year to document the reproductive biology for these species.

- Time of spawning, size at maturity, effective fecundity, annual reproductive effort, and natural mortality were all determined for these species.

- A new method of staining Greenland turbot otoliths for age determination was developed.

Atka Mackerel Ecology

(Task III: D. Gunderson, PI; A. Cooper, S. McDermott)

The goal of this project was to develop a method of estimating local population sizes with respect to Steller Sea lion trawl exclusion zones. A tagging program for estimating population sizes and movement rates for Atka mackerel was developed in previous years, and we continued to participate in the NMFS tagging cruises for this species.

Goal 1: To participate in NMFS atka mackerel tagging cruises

Accomplishment:

- Participated in NMFS Atka mackerel tagging cruises.

Goal 2: To develop a method for using egg production to estimate population size, with further collection and processing of ovarian samples.

Accomplishment:

- Collected and processed ovarian samples for population size estimate based on egg production.

Biology of Skates

(Task III: D. Gunderson, PI: M. Matta)

Goal: To describe the reproductive biology, size at maturity, and fecundity of deepwater skates (Bathyraja parmifera) and develop a technique for age determination.

Accomplishments:

- Collected reproductive tissues, vertebrae, and other structures.

- Began initial analyses on age determination.

Assessment of Fine-Scaled Interactions Between Steller Sea Lion Abundance and Trends of Local Fisheries

(Task III: J. Skalski)

The overall goal of this study was to assess the fine geographic scale interactions between Steller sea lion abundance trends and the abundance of local fisheries and commercial fishing efforts.

Goal 1: Estimate localized rates of population change for Steller sea lions.

Accomplishments:

- Census counts of Steller sea lions at 54 different trend sites and rookeries over the period 1976 to 2002 were analyzed. These 54 locations were ultimately combined to form 34 different populations with spatially distinct population trends.

Goal 2: Assemble fish stock databases.

Accomplishments:

- Fish databases were assembled.

- The triennial bottom-trawl surveys, 1983-2002, were used to estimate the local abundance of walleye pollock, Pacific cod, Atka mackerel, and arrowtooth flounder within a 40 nmi radius of each haulout or rookery cluster [Alaska Fisheries Science Center's Resource Assessment and Conservation Engineering Division (RACE)] database.

- For the years 1990-2002, fishery effort data were obtained from the North Pacific Groundfish Observer Program (NPGOP) database. Fishing effort within 40 nmi of haulout or rookery clusters were summarized for both longline and trawl fisheries for boats >60 ft. Effort was expressed in terms of boat days.

- Herring abundance was characterized by spawning indices, 1973-2002, obtained from the Alaska Department of Fish and Game. The herring abundance was expressed in terms of spawn mile-days and was considered a reliable index of annual abundance.

Goal 3: Conduct relational statistical analyses.

Accomplishments

- Multiple regression analysis using log-linear models or general estimating equations (GEE) were used to investigate the relationships between the instantaneous rates of population change of Steller sea lions within sites over time and across rookeries and haulout areas with localized fish abundance and fishing effort. Based on this analysis, it appears the longline fishery is more likely to more negatively impact Steller sea lion population trends than the trawl fishery is. The factors investigated in this study have a

relatively small incremental effect on Steller sea lion trends. In most cases, these effects are much smaller than the rates of decline seen in the 1970s and 1980s.

Hydrothermal Vents

(Task II: **D. Butterfield, J. Resing**, K. Roe, G. Lebon)

Mid-ocean ridge hydrothermal systems have been studied intensively since the late 1970s, but there are still many geologic environments on the seafloor that have not been investigated, and recent discoveries remind us that there is still much that we have not seen on the seafloor. At present, the classic mid-ocean ridge (or divergent plate margin) environment is relatively well documented, but volcanic arcs (convergent plate margin) and off-axis environments are not. Hence,

Goal 1: To characterize the chemistry of hydrothermal fluids from volcanic arcs, back arcs, and off-axis sites.

Accomplishments.

- In the past 2 years, fluids from two environments that are very different from the classic mid-ocean ridge have been sampled and analyzed. Under NSF support, in 2003 samples were obtained from the off-axis hot spring site near the Mid-Atlantic Ridge, the Lost City hydrothermal field (Butterfield, Roe). The Hydrothermal Fluid and Particle Sampler was used on the submersible Alvin to recover A large number of samples from a range of vents in this new class of hydrothermal field. Unlike volcanic systems directly on the mid-ocean ridge axis, a large portion of the heat coming from this system may result from exothermic chemical reactions between seawater and mantle rocks (peridotites).

- Another major project, funded by NOAA Office of Ocean Exploration, has sponsored two field expeditions in an area of the ocean that was nearly unknown to science, the undersea portion of the Marianas Volcanic Arc between Guam and Iwo Jima. The first expedition (March 2003) generated high-resolution bathymetric maps and water-column surveys of hydrothermal signals (Resing and Lebon). The second expedition (March/April 2004) used the mapping work to locate, sample, and explore seafloor volcanic and hydrothermal features on six submarine volcanoes (Butterefield, Roe, Lebon) . Some remarkable discoveries were made along the way, including the first direct observation of volcanic activity in the deep sea, overlapping hydrothermal and photosynthetic ecosystems, and venting of liquid carbon dioxide (see http://oceanexplorer.noaa.gov/explorations/04fire/). Water samples from this expedition, collected with the PMEL Hydrothermal Fluid and Particle Sampler, are still being analyzed. This is the first major expedition to sample multiple sites on a submarine volcanic arc and adds significantly to the global database for arc volcanoes. The results confirm that arc volcanoes release fluids with extremely high gas content and extreme variation in vent fluid chemistry.

- In April/May 2004 exploratory research (Resing, Lebon) was also conducted in the relatively unexplored Lau Back Arc Basin along the East Lau Spreading Center (ELSC).

This research was funded by NSF's Ridge 2000 program as part of an effort to develop an Integrated Study Site on the ELSC. The ELSC has the most striking and pronounced gradients in fundamental geophysical properties of any similar length of spreading axis on the globe. This makes the ELSC a particularly exciting place to study the interplay between magmatic and hydrothermal processes. During this cruise, we documented the extent and nature of hydrothermal activity along the ELSC. We found that hydrothermal plume incidence vs. spreading rate on the ELSC exceeds that on MORs and increases with spreading rate (mantle heat input) and faulting intensity indicating that these parameters have a greater effect on hydrothermal activity than the rate of magmatic input.

Goal 2: To understand how submarine hydrothermal systems evolve over time and how they respond to local and regional tectonic or volcanic events.

Very little is known about how hydrothermal systems change when they are perturbed by geological events, and the prospect of recording data and collecting samples immediately after an event promises to yield new insight into the workings of hydrothermal systems. Volcanic events have been seen to give rise to microbial blooms, but the chemical conditions that lead to increased biomass in vent fluids have not been measured.

Accomplishments

- JISAO scientists (Butterfield, Roe) are working with a large cast of investigators from the University of Washington and several other institutions on experiments to link seismic activity and hydrothermal processes (especially chemical and microbiological processes) along the Endeavour segment of the Juan de Fuca ridge and the Nootka fault zone adjacent to Vancouver island. This work, which is supported for 5 years (2001-2006) by the W. M. Keck Foundation, involves instrument development and experiments in the field. Three time-series samplers for chemistry and microbiology were deployed for a year and recovered during an Alvin submersible expedition in June of 2004. Many different instruments are deployed at the same time in an inter-disciplinary approach to understand the links between physical, chemical, and biological processes in hydrothermal systems.

- JISAO scientists have pioneered the use of acoustic/satellite systems to enable two-way data transmission between the seafloor and shore-based laboratories. The NeMO satellite/acoustic link observatory at Axial Volcano was successfully installed again, with one interactive water sampler and a bottom pressure recorder. The NeMO-Net project is the first to return data via acoustic modem and satellite from a deep-sea site. This system has been working since 1999, and data are displayed in near real-time on the internet (*http://www.pmel.noaa.gov/vents/nemo/realtime/index.html*). Two-way communication allows direct modification of a seafloor sensing and sampling instrument, so that the sampling rate can be changed, special routines initiated, or immediate return of sensor data requested. Sensors include temperature and pH, with the addition this year of a redox (Eh) sensor. Recovered filters and water samples allow extensive chemical analysis to detect changes related to volcanic activity or long-term evolution. Progress continues in

the development of this new and intricate technology for monitoring the composition of hydrothermal vents in an active volcano.

- Water samples were collected again at Axial Volcano using the hydrothermal fluid and particle sampler. Hydrothermal plumes samples were collected from above the Volcano for the sixth consecutive year. In addition moored instruments within the plumes were recovered. This work is funded by the NOAA Vents program, with additional funding from NOAA West Coast and Polar Regions Undersea Research Center.

Hydrothermal vents represent outcrops on the seafloor of different portions of the thermal and chemical gradients that exist in the sub-seafloor hydrothermal system and therefore provide a window into sub-seafloor chemical and biological processes. It is hypothesized that chemosynthetic organisms living in submarine hydrothermal systems depend directly on the geochemical environment for energy, and that in turn microbial activity may modify the chemical composition of the hydrothermal system. However, very little data exists to verify this hypothesis, and the details of how microbial communities vary with the geochemical environment are unknown. Hence,

Goal 3: to understand the link between the chemical environment and microbial communities in hydrothermal vents.

Accomplishments

- A unique sampling tool has been developed (Butterfield, Roe) that can take clean water samples and concentrate microbes on filters from the same location, while recording the temperature of the vent fluid in order to control sample quality. This sampler has been used extensively since 1998 to collect an unprecedented suite of samples that are being analyzed for their chemical and microbial content. A significant innovation includes the addition of an in-situ preservative for the extremely short-lived rna molecule to reveal the true in-situ activity of hydrothermal microbes. Research activities to support this goal have been sponsored by the PMEL Vents Program, Washington Sea Grant, NOAA West Coast and Polar Regions Undersea Research Center, the W.M. Keck Foundation, and the National Science Foundation. Research in support of this goal has taken place at a wide variety of sites, and has involved the efforts of several graduate students in the U.W. School of Oceanography.

In a project funded by NSF (Butterfield, Roe), microbial community structure and hydrothermal fluid composition have been linked at two sites on the Juan de Fuca ridge (NeMO Axial Volcano observatory and the Main Endeavour Field) and two sites on the eastern flank of the Juan de Fuca ridge (Baby Bare seamount and Ocean Drilling Project Hole 1026B). The field work for this project included the use of a new breakaway coring instrument to penetrate 1.5 to 3 meters below the seafloor at Baby Bare seamount and collect fluids from the stainless steel spikes. Fluids were also recovered from Ocean Drilling Program Hole 1026B, Endeavour Main Field, and Axial SE caldera. The second of two cruises took place in July, 2003 as part of this project to understand sub-seafloor microbial communities in varied environments, including active, volcanically driven hydrothermal systems on the Juan de Fuca ridge axis, and older hydrothermal systems operating at lower temperatures on the east flank of the Juan de Fuca ridge.

Coastal Oceanography

Tsunami Research Program (TRP)

(Task II: Gonzalez, **Arcas,** Bernard, Eble, Mofjeld**, Newman, Titov, Venturato)**

The Tsunami Research Program (TRP) conducts research to improve our understanding of tsunami dynamics and develop applications that will reduce the loss of life and property. An important motivation and focus of this research is NOAA's national responsibility to address issues of public safety and economic cost associated with extreme weather and ocean hazards, including tsunamis. Consequently, NOAA organized and leads the U.S. National Tsunami Hazard Mitigation Program (NTHMP), a Federal/State collaborative partnership of NOAA, USGS, FEMA, NSF and the Emergency Management and Geotechnical agencies of the five Pacific states – Alaska, California, Hawaii, Oregon and Washington. The complementary *NOAA Research Strategic Plan for FY 2003 – FY 2008 and Beyond* identifies four important strategies to achieve Mission Goal 3: *"Monitor and Observe," "Understand and Describe,"* and *"Assess and Predict"* the physical phenomena of interest, and *"Engage, Advise, and Inform"* current and potential users. Each of these NOAA Research Strategies are employed by and are implicit in the specific goals and accomplishments of TRP Research and development, summarized below.

Goal 1: To improve tsunami detection and measurement.

Accomplishment

- **Supporting ongoing tsunami measurement programs**. Accurate and reliable deep-ocean and coastal tsunami measurement networks are crucial to the success and continuing development of tsunami forecasting capabilities. The Tsunami Research Program continues to provide scientific support for Project DART (Deep-ocean Assessment and Reporting of Tsunamis) which has developed a tsunameter measurement system and established a deep-ocean network that provides tsunami data in real-time. Operational responsibility for the tsunameter network is being transferred to the NOAA National Data Buoy Center, and the Tsunami Research Program will continue to support NDBC efforts to improve the quality and reliability of the network. The Tsunami Research Program also provides scientific support for NTHMP efforts to improve the tsunami measurement and reporting capabilities of the Pacific-wide coastal tide gage

network maintained by Pacific Rim countries and, in the U.S., by the NOAA National Ocean Service.

Goal 2: To improve tsunami hazard assessment.

Accomplishments

- **Developing community-specific inundation maps**. Research is conducted by the Tsunami Research Program to improve our understanding of tsunami dynamics, to exploit this understanding for improvements in tsunami numerical modeling technology, and to apply this technology to the development of community-specific inundation maps that describe the potential hazard. These maps are essential tools for State Emergency Management and Geotechnical officials responsible for hazard mitigation, education, and disaster planning and response. The NOAA Center for Tsunami Inundation Mapping Efforts (TIME) was established to support such modeling and mapping efforts in the NTHMP partner States.

- **Assisting the state of Washington in assessing tsunami hazards.** The TIME Center has completed two tsunami modeling studies for the State of Washington. A report on the Seattle tsunami modeling study has been completed, and both hard copy and electronic versions of the inundation model output have been delivered to Washington State Emergency Management and Geotechnical officials. Subsequently, State officials have used the model output to develop and, after review by the TIME Center, publish the official Washington State tsunami inundation map. Similarly, a report on the Straits of Juan de Fuca tsunami modeling study is complete, and the inundation model output have been transferred to State officials. Two official Washington State tsunami inundation maps have been drafted and are in review by the TIME Center.

- **Assisting other states.** The TIME Center also assists tsunami inundation modeling and mapping efforts in Alaska, California, Hawaii, and Oregon, including the acquisition, quality control and distribution of bathymetric and topographic data and computational grids and the development of methodologies for grid construction. The TIME Center continues to improve tsunami modeling techniques, and the latest version of the MOST model for tsunami propagation and inundation has been tested against new benchmark cases. An updated tsunami inundation model has been provided to California.

Goal 3: To improve tsunami warnings.

Accomplishment:

- **Developing forecasting tools**. The Tsunami Research Program is now developing tsunami forecasting tools for NOAA Tsunami Warning Centers (TWC) based on methodologies developed at PMEL. This effort integrates two technologies – tsunami modeling and the real-time tsunameter network -- to provide real-time tsunami forecasts for warning guidance. The objective for this first year has been achieved – a quasi-

operational, web-based version of the tsunami forecasting tools has been completed and is currently under review and testing by the NOAA TWCs.

Goal 4: Improve state's outreach efforts.

Accomplishment

- **Educating the public.** Tsunami Research Program mapping and modeling products are designed and developed with state outreach efforts in mind. Model output includes animations, GIS files and derived products that facilitate state educational and mitigation programs. In addition, team members provide scientific and technical input to state committees and are frequently engaged as contributors to and active participants in state-sponsored public workshops, presentations and other educational and outreach activities.

Information Technology

The PMEL/JISAO information technology (IT) groups are instrumental in providing support to and developing critical infrastructure for research efforts related to all four Themes.

IT Support for NOAA Research

(Task II: **D. Denbo, W. Zhu, M. Spillane, E. Burger, Nazila Merati)**

Goal 1: To provide information technology support for NOAA research.

Accomplishments:

- **Designing IT management system.** Designed an end-to-end system for the management of all information related to the testing, deploying, and real-time data from Argo floats deployed by PMEL. Presently the Web software is under development. The laboratory software currently uses a MySQL database to keep track of float metadata and produce a metadata product used by the Argo community.
- **Providing IT tools.** Continue to provide tools, like ncBrowse, that PMEL researchers are using to improve their exploration of data stored in netCDF files. (Over 5300 unique sites world-wide have downloaded ncBrowse since its March 20, 2000 release.)
- **Developing scripts and software**. Support has included the development of scripts and software for the display and analysis of observational data.

Goal 2: To develop critical infrastructure for the dissemination, visualization, and analysis of observational and model data.

Accomplishments:

- **Developing OceanShare**. OceanShare, a collaborative tool for the interactive exploration of ocean data by teams of researchers, updated and expanded.

Accomplishments involve expanding and enhancing the collaborative and scientific features of OceanShare. The collaboration aspects of the tool have been greatly expanded to create an easier-to-use and manage system. Session and user list archival enable sessions to be logged and backed up, greatly improving reliability. Security has been greatly improved. Encrypted session keys are now stored on the server simplifying secure session management. Session logs in conjunction with date/time and identity saved in each action makes tracing the history of a session much easier. Data can now be loaded into the collaborative tool from a number of local and remote sites. Gridded, profile, time series, and track data are all available. The graphics have been expanded to support the comparison of station data and gridded model results.

- **Developing/distributing Scientific Graphics Toolkit (SGT)**. Developed and distributed the Scientific Graphics Toolkit (SGT) version 3.0. A Java package that is used in many of the projects described here. SGT has recently been extended to enable novice users access to Java scientific graphics through the SGT Beans interface. (Another popular Java package, SGT has had over 22,000 downloads from over 7400 unique sites world-wide since March 2000.) The SGT class library and source code are available from the web.

- **Developing OPeNDAP server.** Developed an in-situ data OPeNDAP (formally DODS) compatible server. The "Dapper" server provides access to oceanographic observational data using the Climate Data Portal backend and the EPIC profile/time-series databases. Several programs can directly access the Dapper server, including, Java Ocean Atlas (JOA), ncBrowse, and OceanShare.

- **Enhancing Live Access Server.** Enhanced the Live Access Server (LAS) was further enhanced to use in-situ data from the Dapper server. Extended LAS functionality by increasing the flexibility for configuration and adding new features for data visualization and analysis.

- **Utilizing virtual reality technology**. Used virtual reality hardware to display physical and biological model output from GLOBEC and other programs at conferences, workshops and schools.

Goal 3: To advance lowest video conferencing among oceanographers.

Accomplishment:

- **Developing video conferencing capabilities.** Implemented Personal Access Grid hardware and software on local PC's at PMEL.

Thermal Modeling and Prediction (TMAP)

(Task II: S. Hankin, **J. Callahan, K. O'Brien, J. McLean**)

Goal 1: To provide software solutions that integrate and disseminate data and data products over the Internet.

Accomplishments:

- **The Live Access Server (LAS).** The Live Access Server is currently installed at approximately 50 institutes worldwide and provides access to terabytes of ocean, atmosphere and climate data. In the last year LAS was enhanced year to provide access to non-gridded data and associated data products. Enhancement of LAS features and products is ongoing.

- **The Ferret Data Server (FDS).** The Ferret visualization package has been enhanced to function as an OPeNDAP data server. This unique package provides the full data analysis capabilities of Ferret as a web service available to other software packages. Data comparison of remote data sources will be provided by the unique regridding capabilities available through FDS.

- **Observing System Monitoring Center (OSMC)** at NOAA Office of Global Programs. A custom interface is being designed for the OSMC that connects to the Live Access Server to provide data visualizations and products. This interface provides an instantaneous overview of the state of the global ocean monitoring system.

- **Support for Hybrid Coordinate Ocean Model (HYCOM).** Enhancements have been made to the Ferret visualization package and the Live Access Server to accommodate curvilinear coordinate models such as those used by HYCOM. It is now possible to regrid curvilinear model data to a rectilinear grid for comparison with other models.

Goal 2: To provide support for sites utilizing LAS for data access.

Accomplishments:

- **Argo Global Ocean Data Assimilation Experiment (GODAE) server in Monterey.** The Live Access Server was installed at the Navy's Fleet Numerical Metereology and Oceanography Center and is currently being used to provide access to data and data products. The GODAE server in Monterey is designated as an official US GODAE server for real time data products.

- **IPRC server in Honolulu.** The Live Access Server was installed at the Asia Pacific Data Research Center (APDRC) at the University of Hawaii. The APDRC server is designated as an official US GODAE server for archive data and data products.

Goal 3: To develop data management solutions that make large volumes of oceanographic data accessible to users on demand in real-time.

Accomplishment:

- **Carbon Data Management.** TMAP is working with the Carbon Dioxide Information Analysis Center at Oak Ridge National Lab to design a data management system that will provide real-time access to a unique collection of ocean carbon measurements including 'underway' data, profiles and time series. The initial data base schema has been implemented and hooked up to LAS to provide an end-to-end data management and visualization system for these types of data.

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Selected Honors and Awards

- Senior Fellows Richard A. Feely and Christopher L. Sabine were lead author and co-author (with T. Takahashi and R. Wannikov) on the paper "Uptake and storage of carbon dioxide in the oceans" (Oceanography, 14(4), 18-32 (2001) which won the NOAA OAR 2002 Outstanding Paper Award.

- Senior Fellow Michael McPhaden received the Grace Hopper Government Technology Award ("Gracie Award") on behalf of the TAO Project for leadership in the innovative application of information technology (December 2003). McPhaden was also named one of the University of Colorado's Destinguished Lecturers. He will present his lecture in November 2004.

- Senior Fellow Ed Miles, Director of the JISAO Climate Impacts Group, was elected a member of the National Academy of Sciences.

- Yvonne Ortiz, a collaborator on JISAO Task III projects, received an award for the best poster at the International Symposium for Quantiaitive Ecosystem Indicators in Paris, France, March 31 - April 3, 2004.

- The American Geophysical Union has instituted the James R. Holton Award for outstanding young scientists. Holton was a JISAO Senior Fellow who died in March 2004.

Appendices

Appendix 1

JISAO Senior Fellows

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Appendix 2

Task I Program Workshops and Special Events 2003-04

July 2003

7-11: PALEO Workshop to discuss aspects of abrupt climate change in the past, including observations and physical mechanisms, and to assess the likelihood that abrupt climate changes may happen in the future, especially in relation to increasing greenhouse gas concentrations. All of the participants will be making presentations (formal and informal) during the course of the workshop.

1. David Battisti, "Understanding Dansgaard/Oeschger Events: Recent developments and remaining issues."
2. John Chiang, "Midlatitude influence on the tropical marine climate: lessons from the tropical Atlantic".
3. Sang-Ik Shin, "North Atlantic thermohaline circulation changes at the LGM from the results of NCAR's coupled climate system model."
4. Jeffrey Yin, "Thoughts on tropical control of midlatitude storm track/mean flow variability."
5. Eric Steig, "Phase relationships between Antarctic and Greenland climate records".
6. Gerard Roe, "Characterization of millennial-scale climate variability".

Joe Barsugli, Eric DeWeaver, Gerard Roe, and Richard Seager attended.

October 2003

13: *Kunihiko Kodera*, Meteorological Research Institute, Tsukuba, Ibaraki, Japan. "AO/NAO/ENSO, and their relationship with solar activity."

16: *Kevin E. Trenberth*, Senior Scientist at NCAR Climate & Global Dynamics Division. "Seamless Poleward Energy Transports and Implications for the Hadley Circulation."

17: *Kevin E. Trenberth,* Senior Scientist at NCAR Climate & Global Dynamics Division. "Problems with Climate Observations and the Need for an Earth Information System."

30: *Hans van Storch*, Professor, Institute for Coastal Research, Germany. "Climate model simulates global cold climate during late Maunder minimum (1675-1710)."

November 2003

03: *Sandy Tudhope*, Edinburgh University, Department of Geology & GeophysicsSen. "Variability in ENSO and Tropical Pacific climate: evidence from living and fossil coral."

26: *Nathan Gillett,* University of Victoria, BC. "Simulating the effect of ozone depletion on Southern hemisphere climate."

December 2003

23: *Paul Schopf,* Professor of Oceanography, Institute for Computational Sciences and Informatics, George Mason University. "Self-regulation of ENSO."

Task I Program (Continued)

January 2004

21: *Rene D. Garreaud,* Professor Assistant of Physical and Mathematical Sciences, University of Chile. "The Diurnal Cycle in Circulation and Cloudiness over the Subtropical Southeast Pacific."

May 2004

27: *Takamitsu Ito,* Post doctorate candidate. "Southern ocean biogeochemistry and the residual mean circulation."

June 2004

07: *Meredith Hastings*, Post doctorate candidate. "Using isotopes to discern sources, transport and chemistry of atmospheric nitrate at Bermuda."

11: *Jessica Lundquist,* Post doctorate candidate. "Spring onset in the Sierra Nevada: When is snowmelt independent of elevation?"

Thomas Peter, Professor, Institute for Atmospheric and Climate Science, Department of Environmental Sciences, ETH Swiss Federal Institute of Technology - Zurich. Professor Peter is a visiting scientist through June and July.

24: *Thomas Peter,* Swiss Federal Institute of Technology-Zurich. "The origin of high ice crystal number densities in cirrus clouds."

29: *Thomas Peter,* Swiss Federal Institute of Technology-Zurich. "Ultra thin tropical tropopause clouds: a measure of mesoscale upwelling."

July 2004

01: *Thomas Peter,* Swiss Federal Institute of Technology-Zurich. "Tracing troposphere-to-stratosphere transport above a mid-latitude deep convective system."

Appendix 3

JISAO Employees Supported by Task II Projects

Name	Title
A'Hearn, Patrick	Research Consultant
Alvarez-Flores, Carlos M.	Research Associate
Bahl, Kimberly	Research Consultant
Boeing, Wiebke	Research Associate
Boldt, Jennifer	Research Associate
Bond, Nick	Meteorologist
Burger, Eugene	Research consultant
Butterfield, Dave	Oceanographer
Callahan, Jon	Research Consultant
Cheng, Wei	Research Scientist
Cianelli, Lorenzo	Research Associate
Coffman, Derek	Research Scientist
Cooper, Dan	Research Scientist
Cosca, Cathy	Research Scientist
Denbo, Donald	Research Scientist
Dobbins, Elizabeth	Research Scientist
Doherty, Sarah	Research Scientist
Dougherty, Daniel	Research Consultant
Doyle, Miriam	Research Scientist
Fey, Curran	Research Consultant
Flosadottir, Agusta	Research Engineer
Hamilton, Drew	Oceanographer
Hermann, Albert	Oceanographer
Jenkins, Antonio	Research Scientist
Johnson, Jim	Oceanographer
Jurado-Molina, Jesus	Research Associate
Kachel, Nancy	Oceanographer
Ladd, Carol	Research Scientist
Lebon, Geoff	Research Scientist
Lee, Yong Woo	Research Associate
Martin, Bill	Research Scientist
Mazur, Michael	Research Associate
McCarty, Marguerite	Research Scientist
McClurg, Dai	Research Scientist
McHugh, Kevin	Research Scientist
McLean, Joseph	Research Consultant
Menzia, Fred	Research Scientist
Merati, Nazila	Research Scientist
Miller, Theresa	Research Scientist
Moore, Christopher	Research Scientist
Mordy, Calvin	Oceanographer
Mueter, Franz	Research Associate

JISAO Employees Supported by Task II Projects

Newman, Jean	Research Scientist
Noor, Sonya	Research Consultant
O'Brien, Kevin	Research Scientist
Parada-Veliz, Carolina	Research Associate
Proctor, Peter	Research Scientist
Resing, Joseph	Research Scientist
Rice, Andrew	Research Associate
Righi, Dylan	Research Scientist
Rodionov, Sergei	Research Scientist
Roe, Kevin	Research Scientist
Sawatzky, Trisha	Research consultant
Sonnerup, Rolf	Research Scientist
Spillane, Mick	Research Scientist
Steele, T	Tech Writer
Stratton, Linda	Research Scientist
Sullivan, Margaret	Research Scientist
Titov, Vasily	Research Scientist
Venturato, Angie	Research scientist
Wang, Muyin	Meteorologist
Wood, Kevin	Research Scientist
Zhang, Dongxiao	Research Scientist
Zhu, Willa	Research Scientist
Zimmerman, David	Research Engineer

Appendix 4

List of JISAO Task III Principal Investigators and Projects:

APPENDIX 4, List of Task III Principal Investigators and Projects

PI NAME	ACADEMIC UNIT	TITLE OF PROPOSAL	FUNDING
BATTISTI, D.	Atmospheric Sciences	Observing System Research Studies	$60,000
BRETHERTON, C.	Atmospheric Sciences	Climate Process Team Collaborative Research on Low-Latitude Cloud Feedbacks on Climate Sensitivity	$178,812
COVERT, DAVID	Atmospheric Sciences	Multiwavelength Measurement of Aerosal Absorption Coefficient	$88,400
DEMING, JODY	Oceanography	Exploring for Novel Cold-Adapted Microorganisms/Vxusiong Actic Expedition 2003	$25,200
GUNDERSON, D.	Aquatic & Fishery Sciences	(Trands in Fish Abundance and Productivity) Greenland Turbot Age Determination	$101,997
GUNDERSON, D.	Aquatic & Fishery Sciences	Biology of Skates	$77,917
HILBORN, R.	Aquatic & Fishery Sciences	Graduate Student Stipend for Stock Assessment Training and Improvement	$72,340
HORNE, J.	Aquatic & Fishery Sciences	Fisheries Acoustics Research	$133,431
HOUZE, R.	Atmospheric Sciences	Further Analysis of the Tepps Data: Relation to ITCZ Convection to Large-Scale Cross-Equatorial Flow	$100,000
KACZYNSKI, V.	Marine Affairs	Capacity Building and Adaptation to the Climate and Environmental Change in Coastal Zones of the Republic of South Africa	$50,000
LETTENMAIER, D.	Civil & Environmental Eng.	Development of Hydrologic Newcasts and Forecast Products using Land Data Assimilation	$55,000
LINDSAY, R.	Applied Physics Lab	Monitoring of Ice Thickness in the Western Arctic Ocean	$28,500
MASS, C.	Atmospheric Sciences	Regional Weather Analysis and Prediction	$124,942
MILES, E.	Marine Affairs	Impacts of Climate Variability and Change on PNW Coastal Watershed Management	$75,000
MILLER, B.	Aquatic & Fishery Sciences	Marine Biological Interactions in the North Pacific-Fish Interactions	$458,728
NAISH, K.	Aquatic & Fishery Sciences	The Molecular Genetics of Pacific Salmonds	$119,454
NYSTUEN, J.	Applied Physics Lab	Long-Term Acoustical Measurements of Air-Sea Exchange Processes: Rainfall Stratiform Drizzle, Ambient Bubbles and Wind Speeed	$30,200
QUAY, P.	Oceanography	Carbon Isotope Constraints on Ocean GCM Simulations of Anthropogenic COZ Uptate	$98,855
RHINES, P.	Oceanography	Oceanic Observatios of Climate Change in the Arctic-Subpolar Zoned	$365,900
RIGOR, I.	Applied Physics Lab.	Monitoring the Eurasian Basin of the Arctic Ocean	$200,000
RISER, S.	Oceanography	The ARGÖ Project: Global Ocean Observation for Understanding and Prediction of Climate Variability	$1.9M
RISER, S.	Oceanography	Chartering the Research Vessel Pavel Gordienko for ARGO use in the South Pacific	$735,000
SARACHIK, E.	Atmospheric Sciences	The Center for Science in the Earth System	$1.59M
SCHWEIGER, A.	Applied Physics La.	Correction of Systematic Errors in TOVS Radiances	$65,000
SKALSKI, J.	Aquatic & Fishery Sciences	Quantative Assessment of Estimation Based on Data Collected by Observer in the North Pacific Ocean	$40,642

APPENDIX 5

Count of Publications

	JI Lead Author			NOAA Lead Author			Total
	FY 01	**FY 02**	**FY 03**	**FY 01**	**FY 02**	**FY 03**	
Peer-reviewed	27	43	33	21	35	61	220
Non peer-reviewed	23	30	15	16	10	21	115
Totals	**50**	**73**	**48**	**37**	**45**	**82**	**335**

APPENDIX 6

Employee Count (FY 2004)[3]

Visitors (Ph.D.s)	17	
Post Docs	9	
Graduate Students	23*	
	Total	**49**

Professional Staff:

	Unknown	
	No Degree	1
	Associate's	3
	Bachelor's	31
	Master's	16
	Ph.D.	30
	Total	**81**

Hourly/Temporary Staff:

	Unknown	1
	No Degree	1
	Associate's	
	Bachelor's	2
	Master's	
	Ph.D.	1
	Total	**5**

*Preliminary estimates.

[3] There were no subcontract employees paid by JISAO. No JISAO employees were hired by NOAA in FY 2004.